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**Daley et al.**

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(54) **SYSTEMS AND METHODS FOR  
SYNCHRONIZING MULTIPLE ELECTRONIC  
DEVICES**

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21/41407

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See application file for complete search history.

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H04H 60/80; H04H 60/27; H04W 88/04;  
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*Primary Examiner* — Yuwen Pan

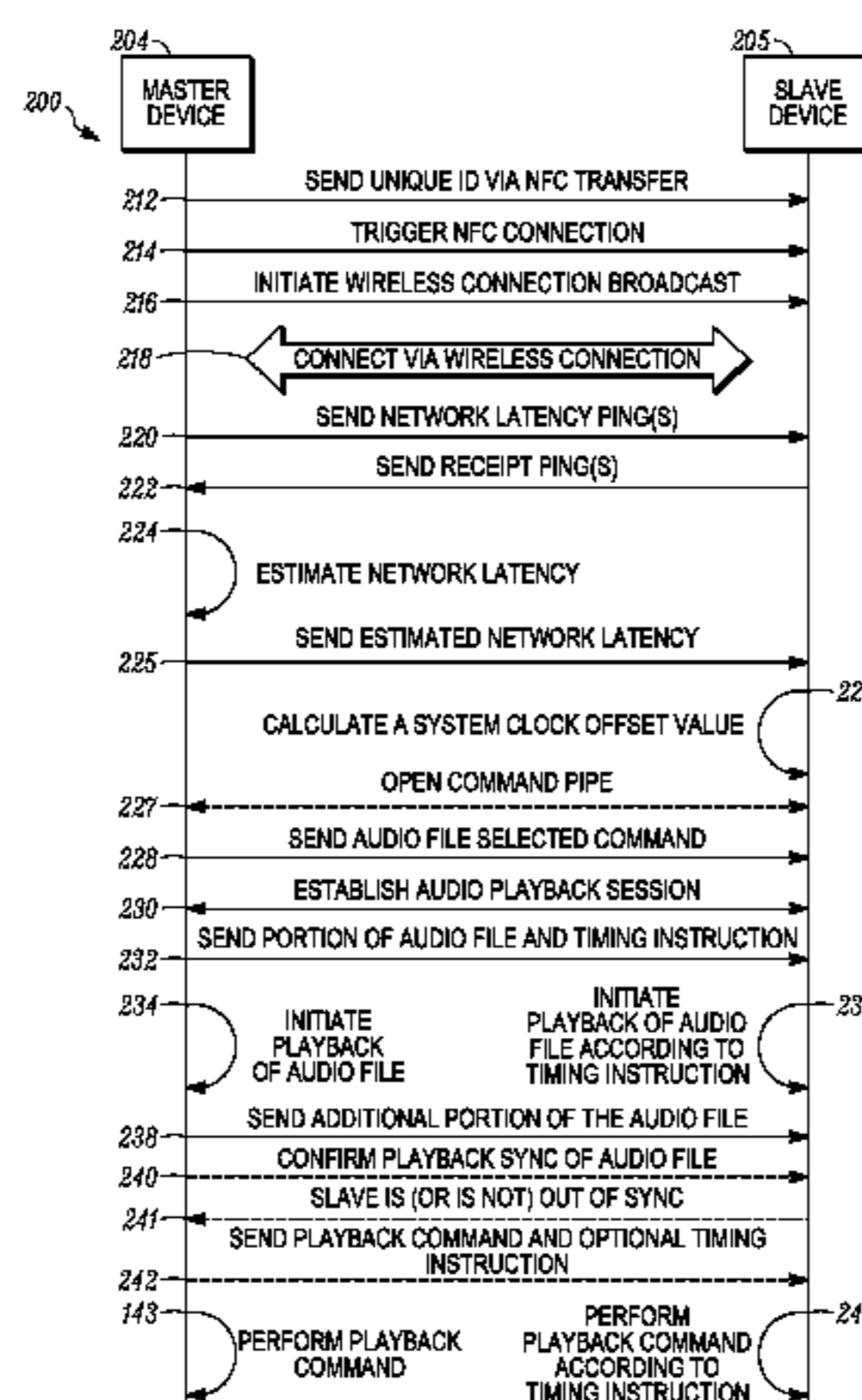
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LLP

(57) **ABSTRACT**

Embodiments are provided for syncing multiple electronic  
devices for collective audio playback. According to certain  
aspects, a master device connects (218) to a slave device via  
a wireless connection. The master device calculates (224)  
a network latency via a series of network latency pings with the  
slave device and sends (225) the network latency to the slave  
device. Further, the master device sends (232) a portion of an  
audio file as well as a timing instruction including a system  
time to the slave device. The master device initiates (234)  
playback of the portion of the audio file and the slave device  
initiates (236) playback of the portion of the audio file accord-  
ing to the timing instruction and a calculated system clock  
offset value.

**9 Claims, 16 Drawing Sheets**



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*H04N 5/932* (2006.01)  
*H04N 5/935* (2006.01)  
*G06F 15/16* (2006.01)  
*H04N 7/173* (2011.01)  
*H04W 56/00* (2009.01)  
*H04H 20/38* (2008.01)  
*H04H 20/61* (2008.01)  
*H04H 20/08* (2008.01)  
*H04H 20/18* (2008.01)  
*H04H 20/57* (2008.01)  
*H04H 20/63* (2008.01)  
*H04H 60/80* (2008.01)
- (52) **U.S. Cl.**  
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 (2013.01); *H04H 20/57* (2013.01); *H04H 20/63*  
 (2013.01); *H04H 60/80* (2013.01)

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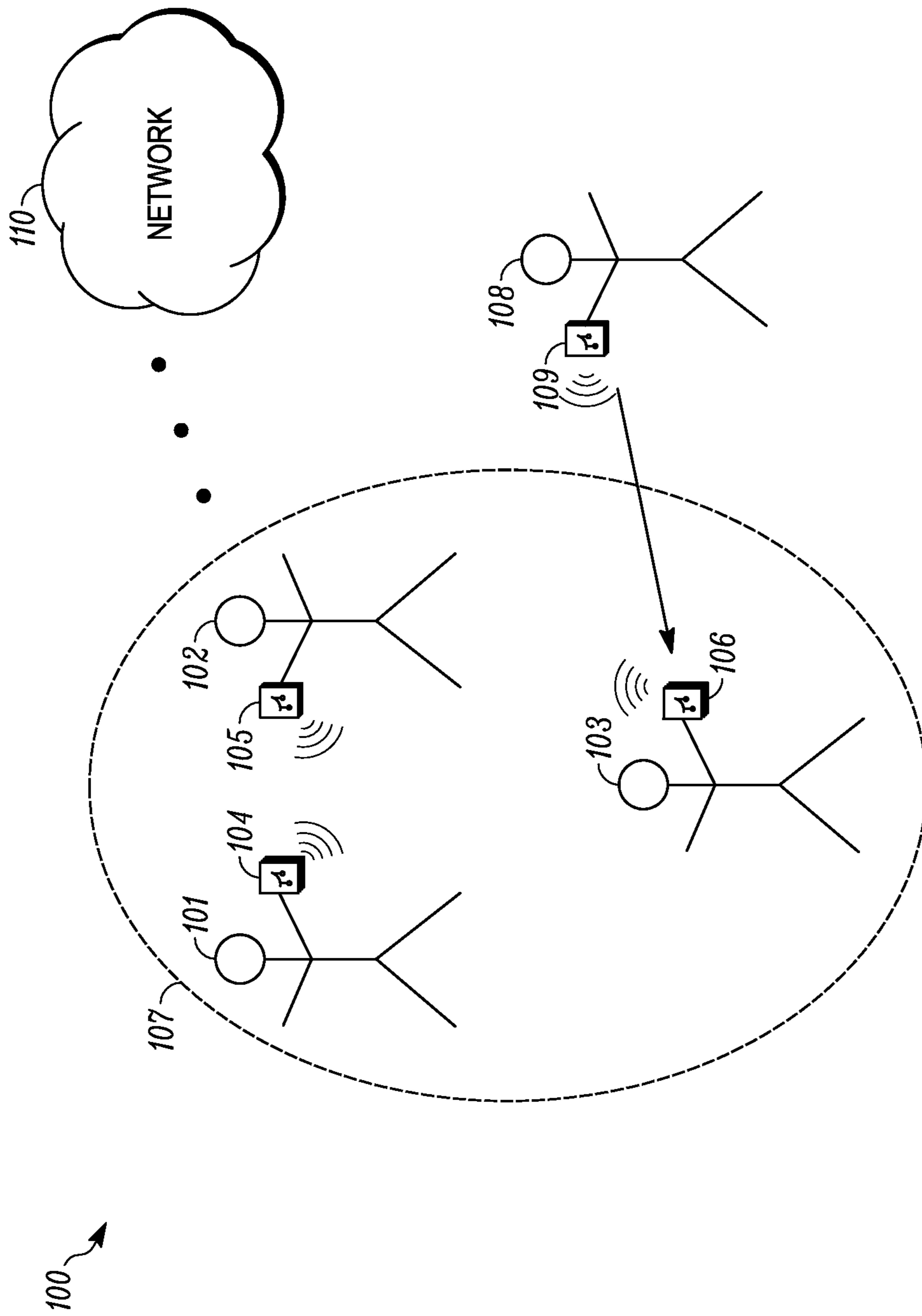


FIG. 1

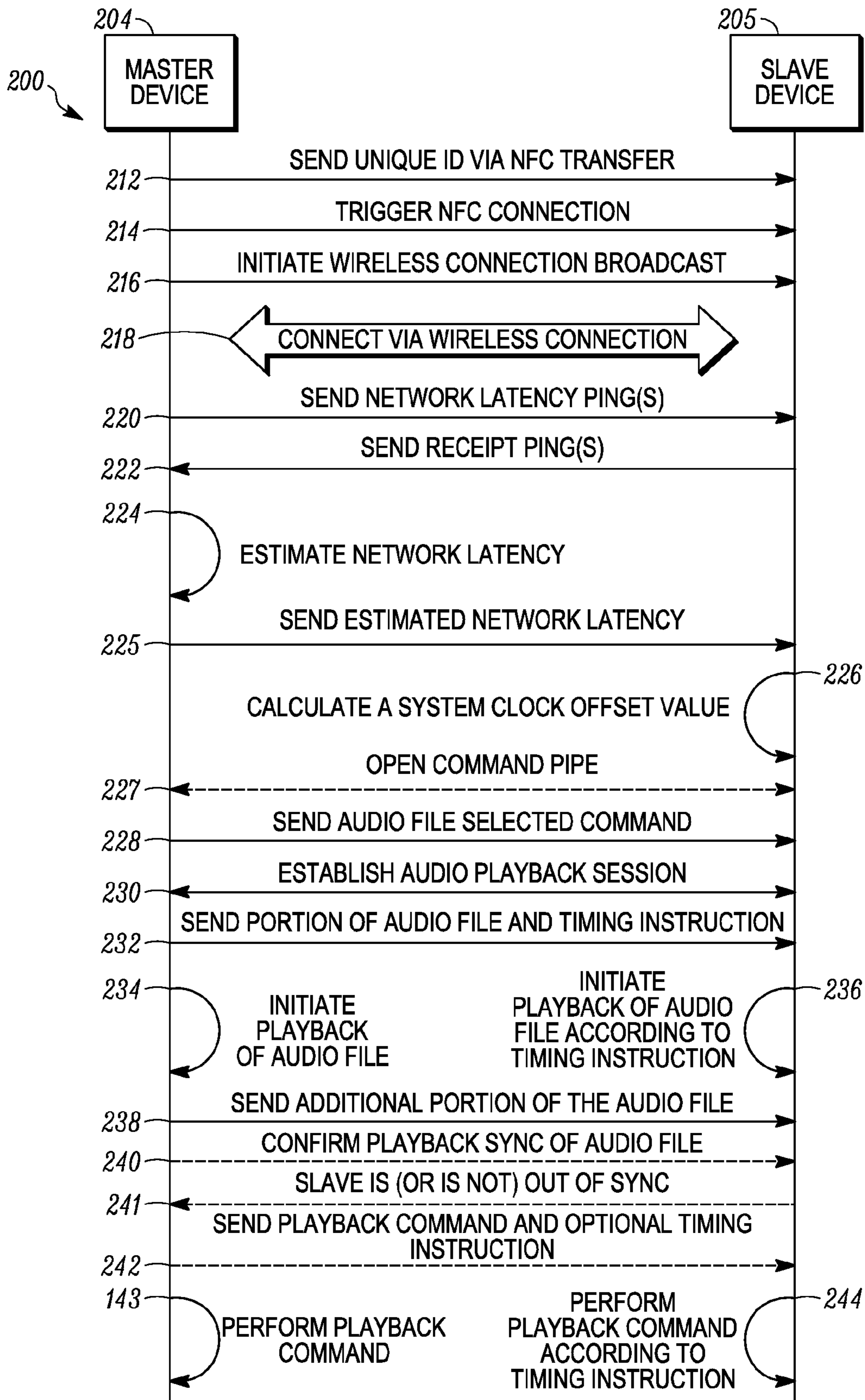


FIG. 2

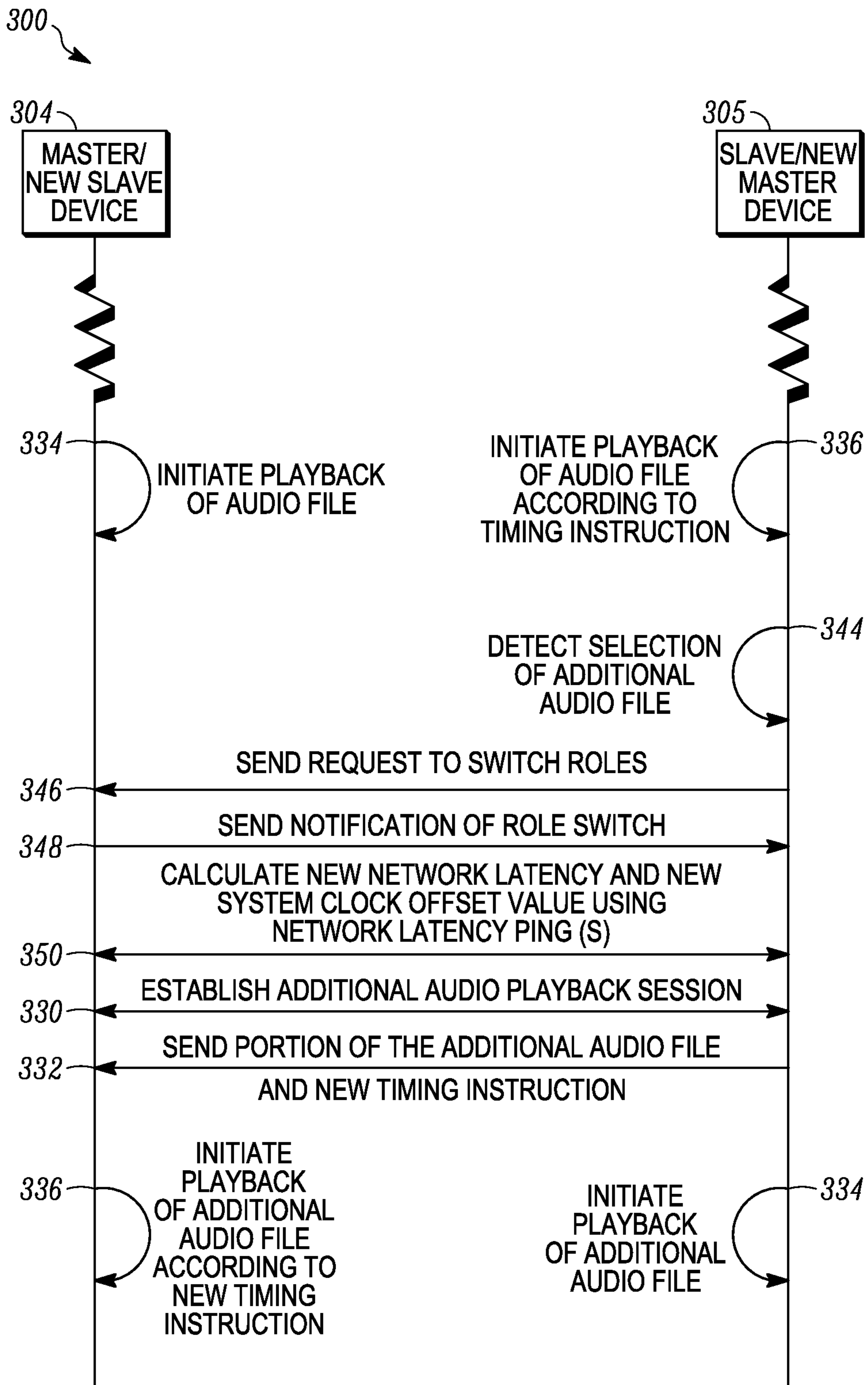


FIG. 3

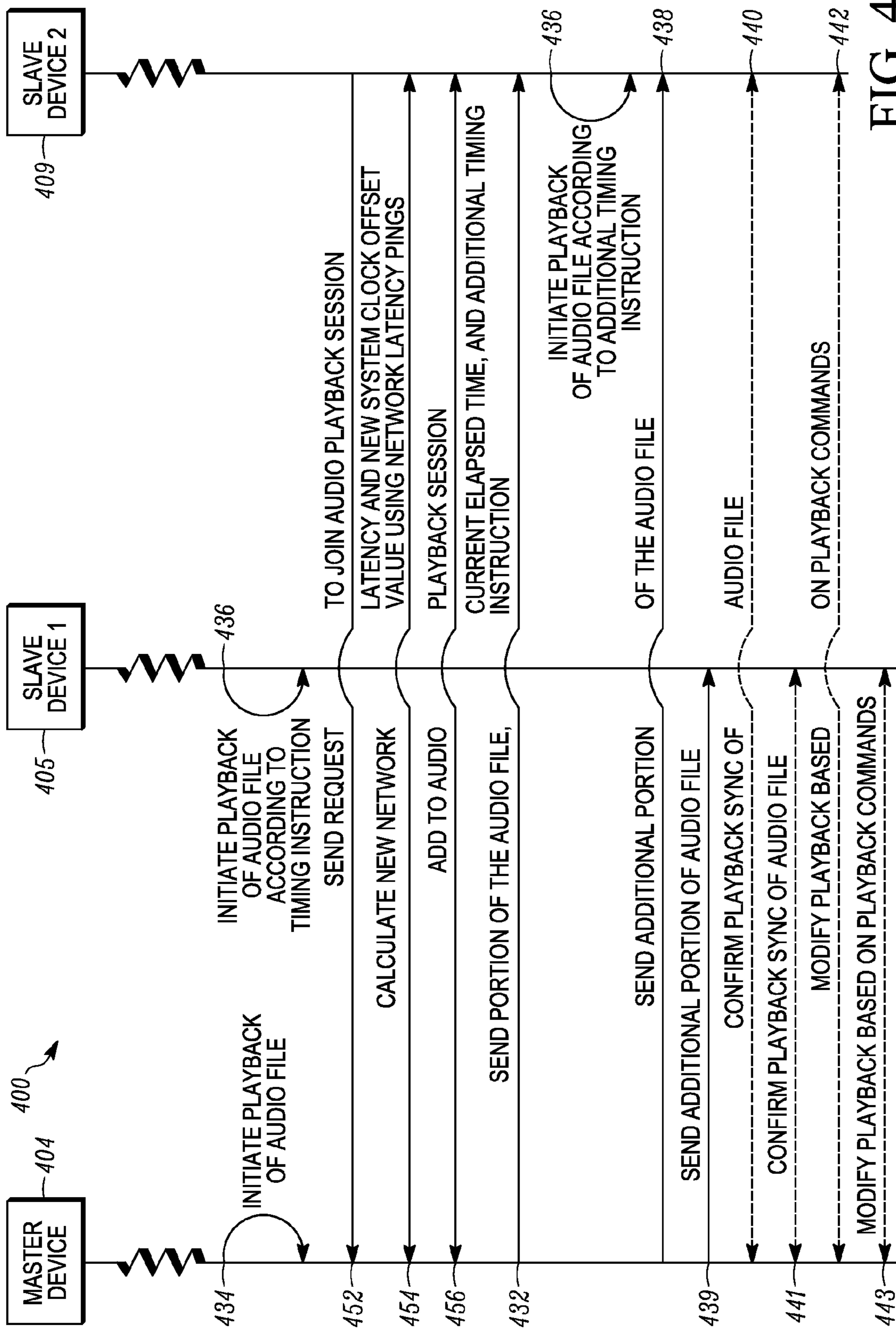


FIG. 4

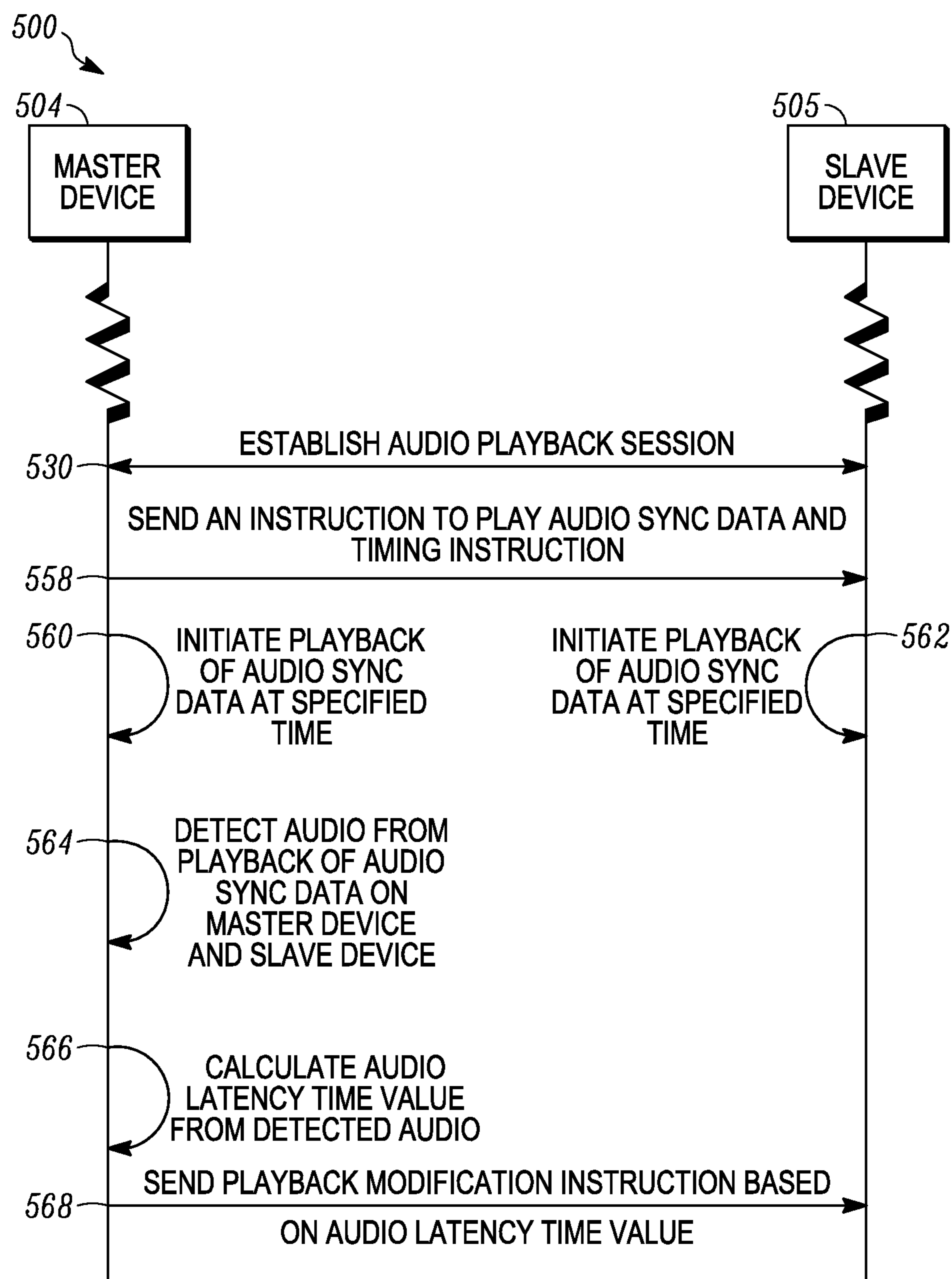


FIG. 5

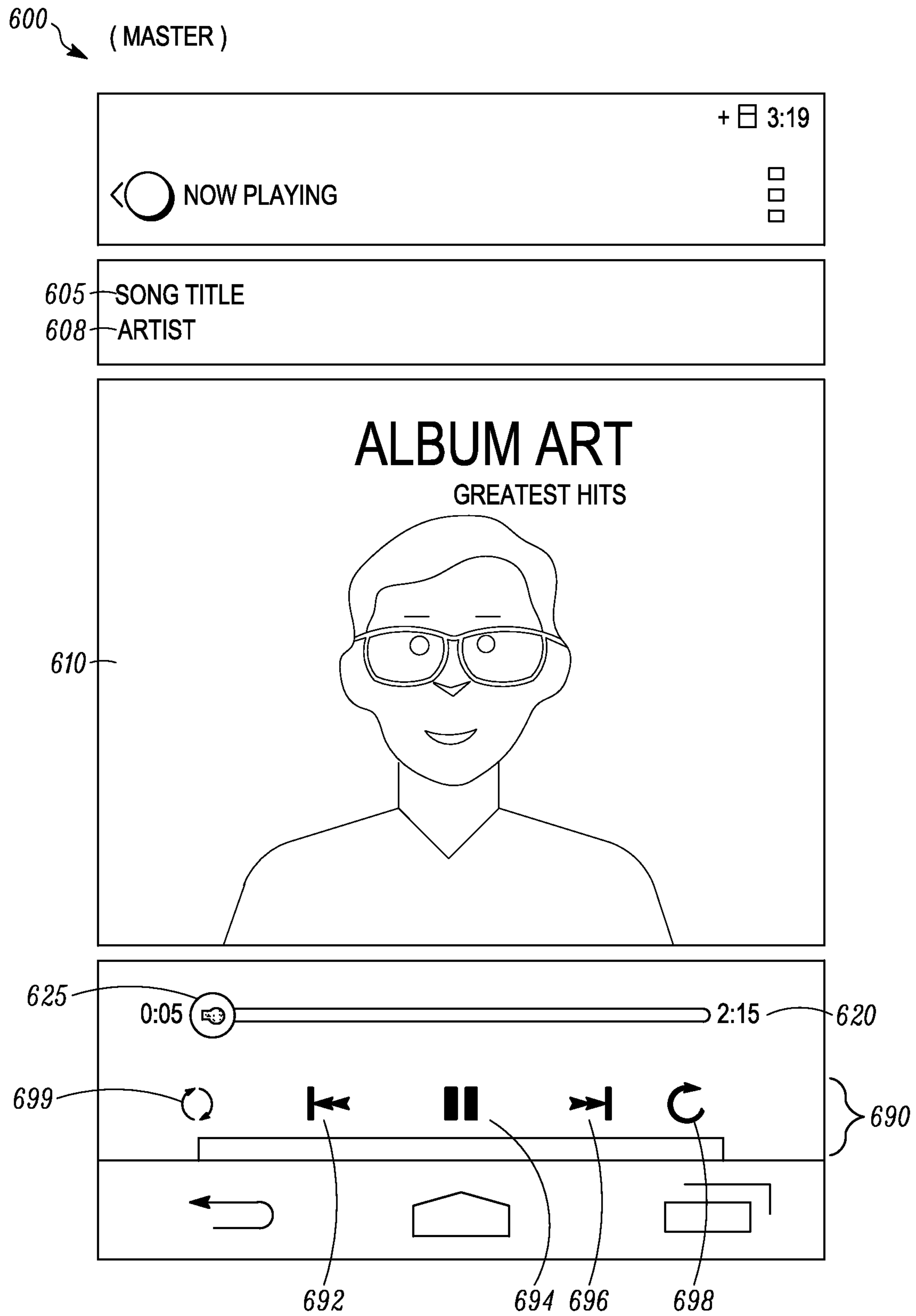


FIG. 6



700 (SLAVE)

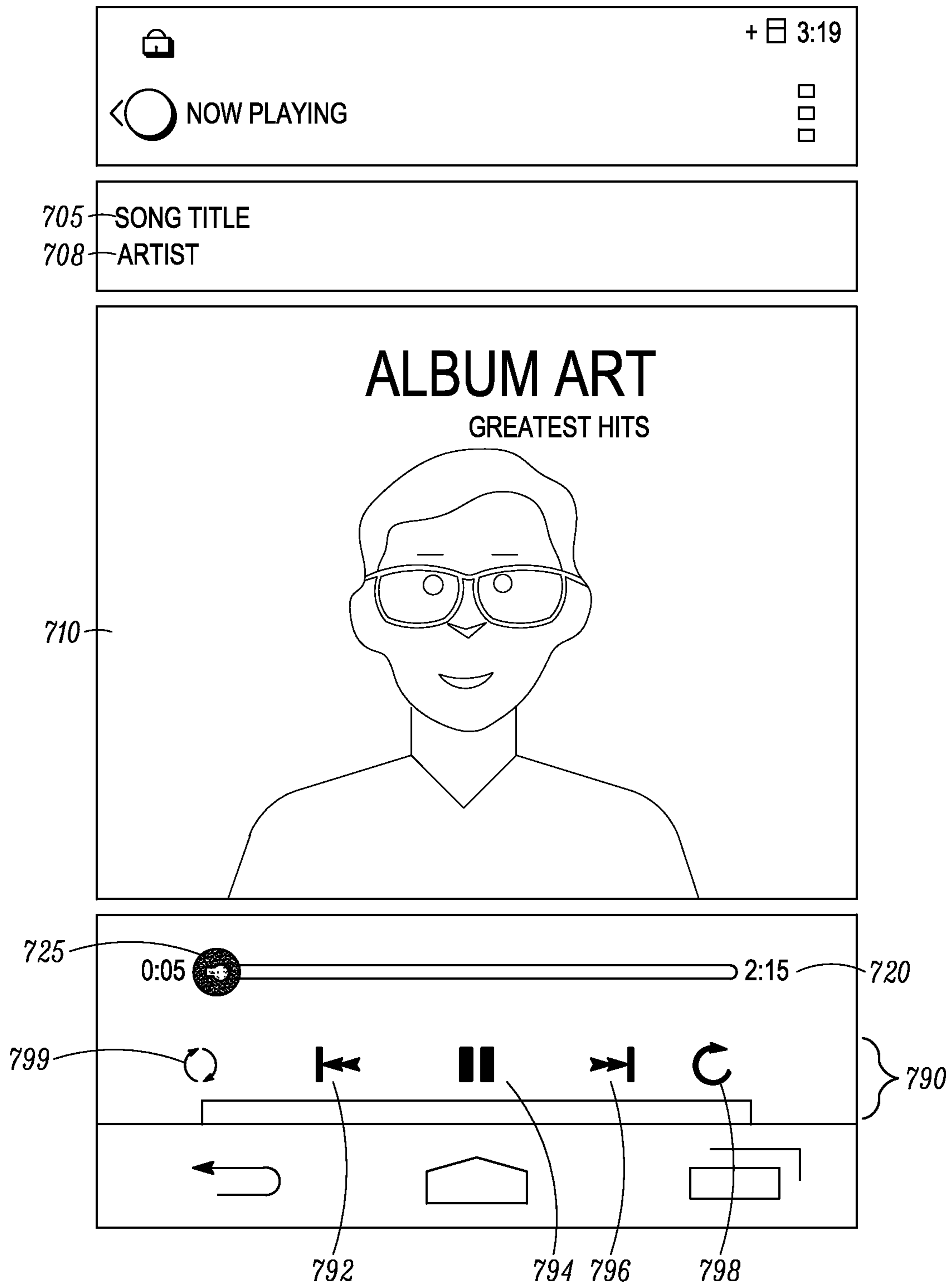


FIG. 7

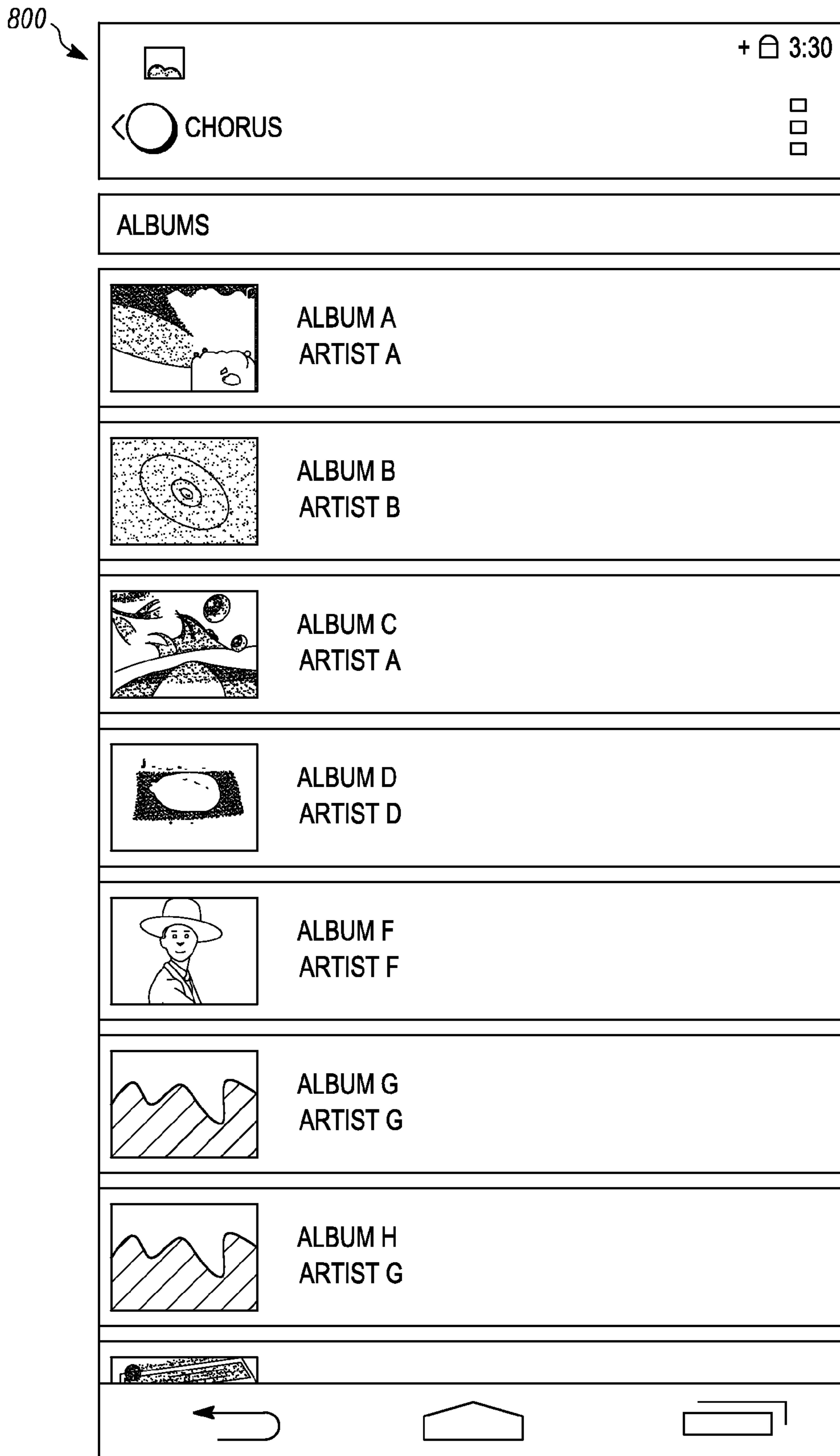


FIG. 8

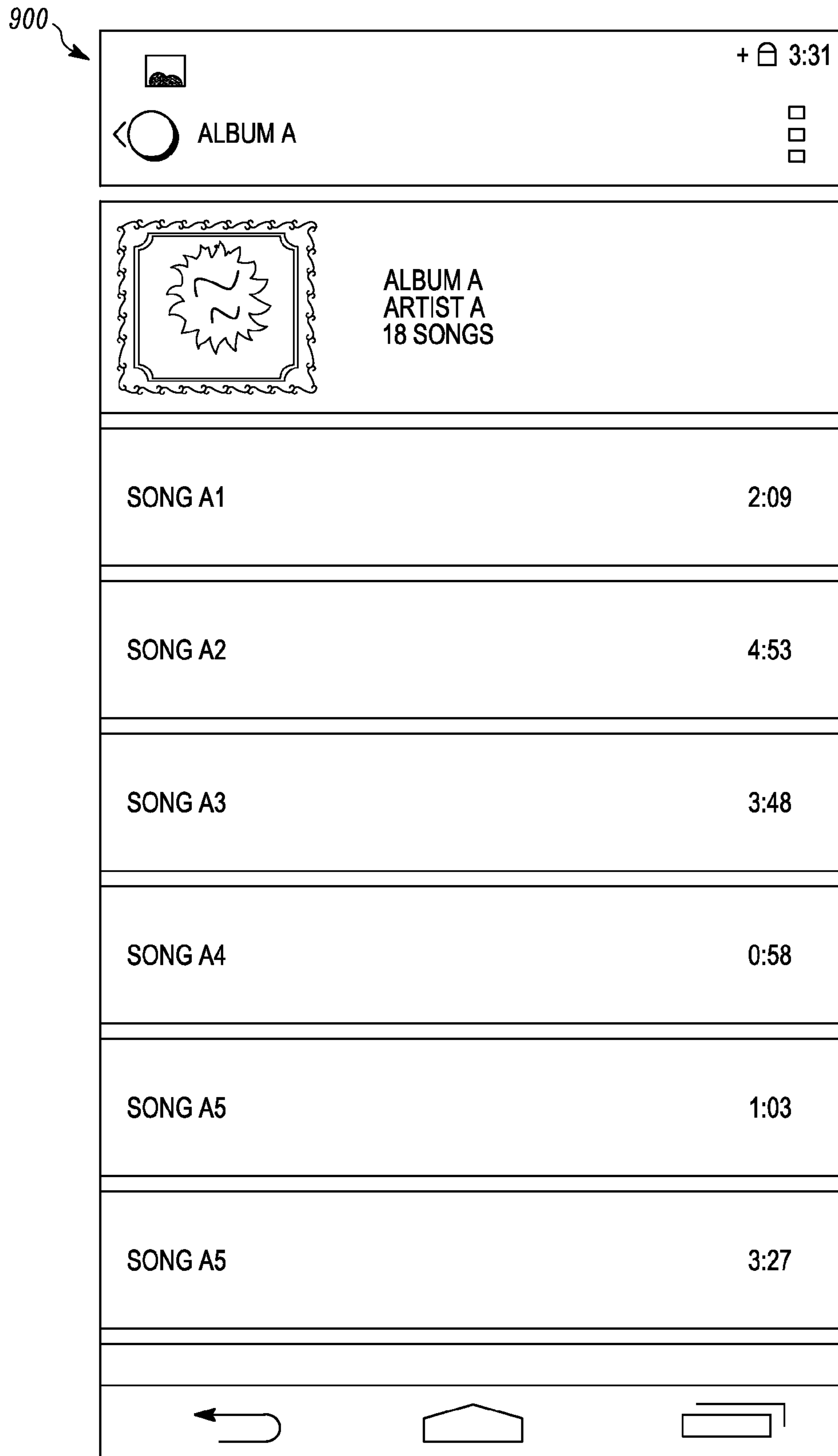


FIG. 9

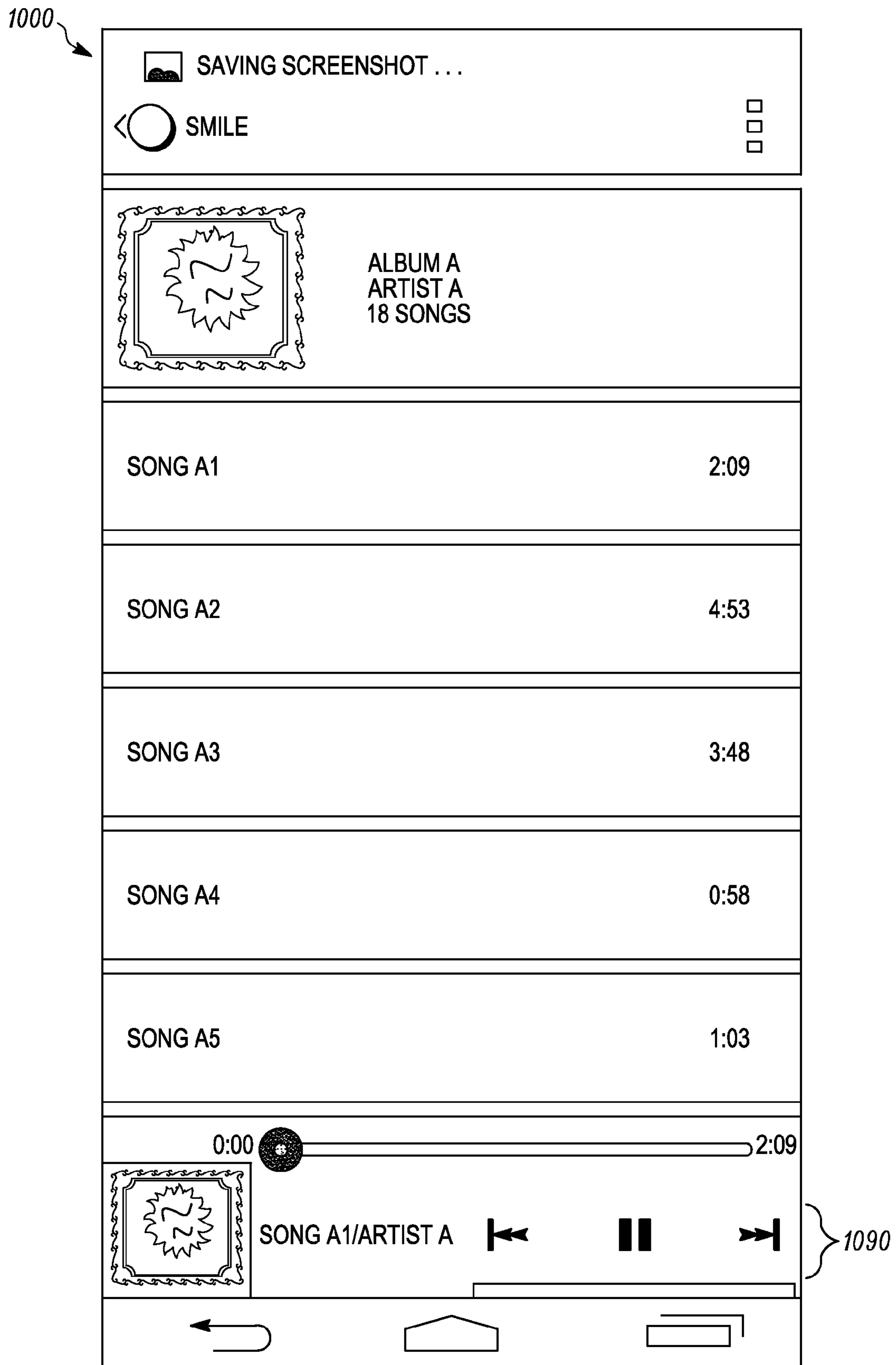


FIG. 10

1100

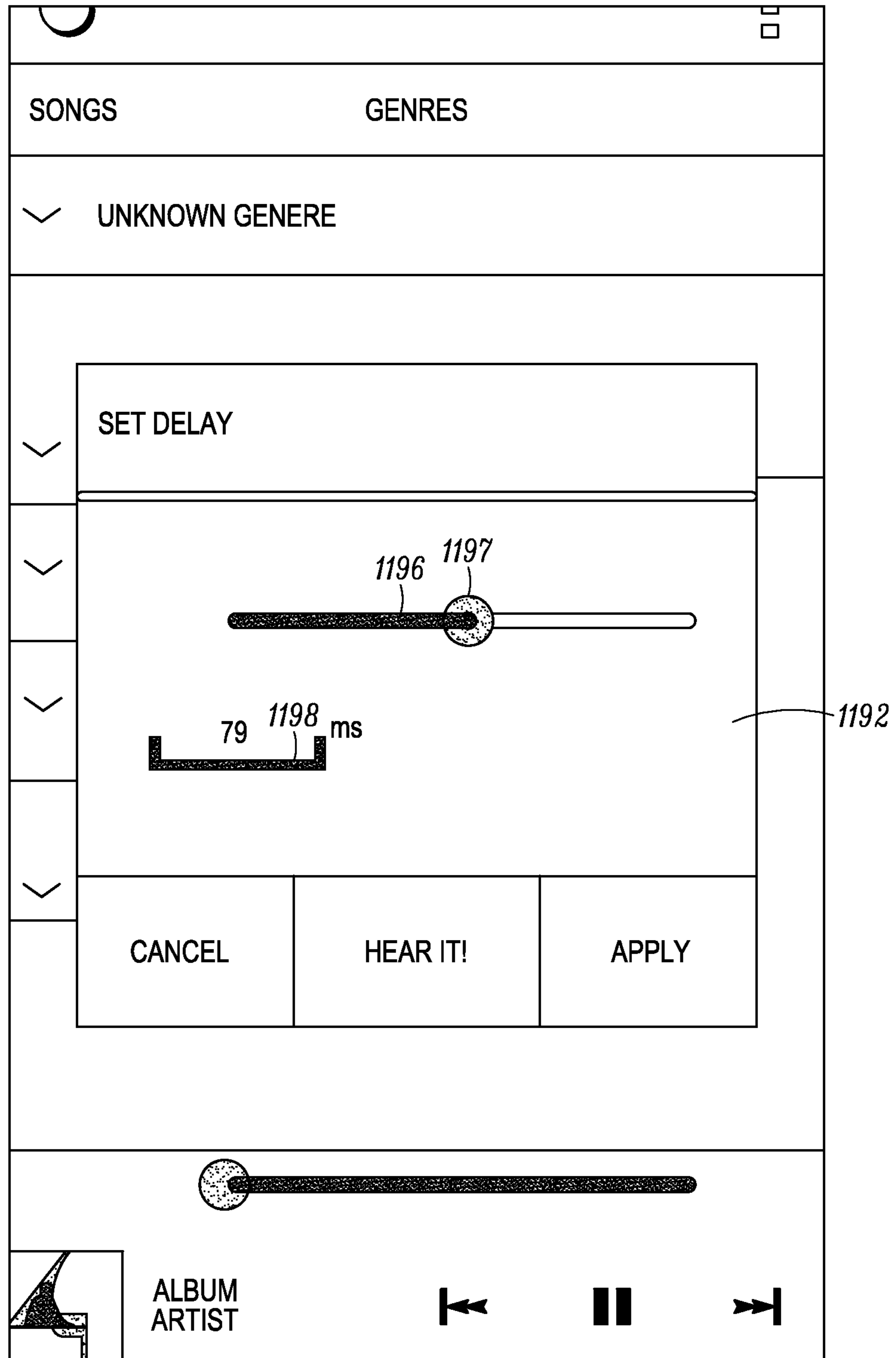


FIG. 11

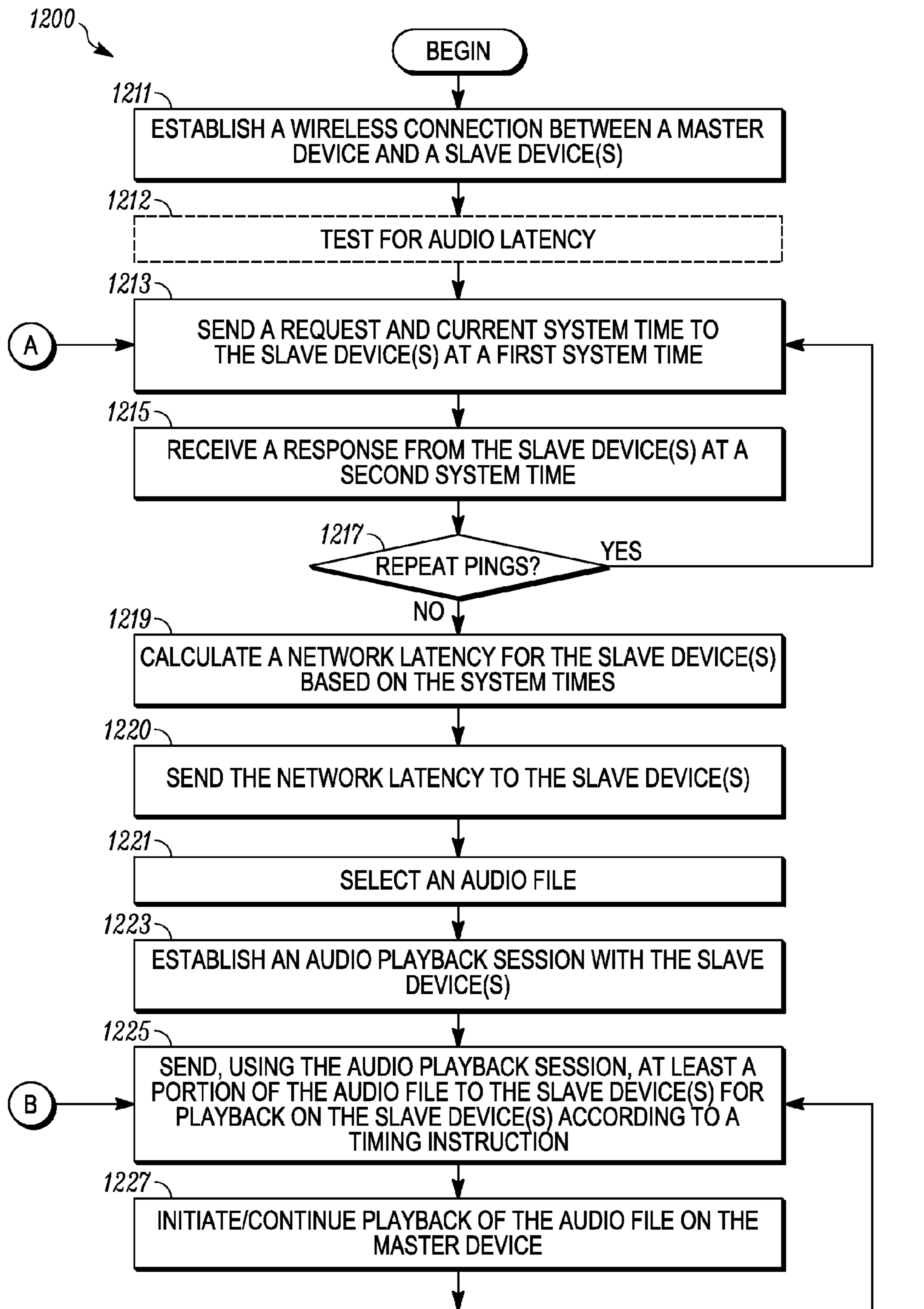


FIG. 12 

FIG. 12A
FIG. 12B

FIG. 12A

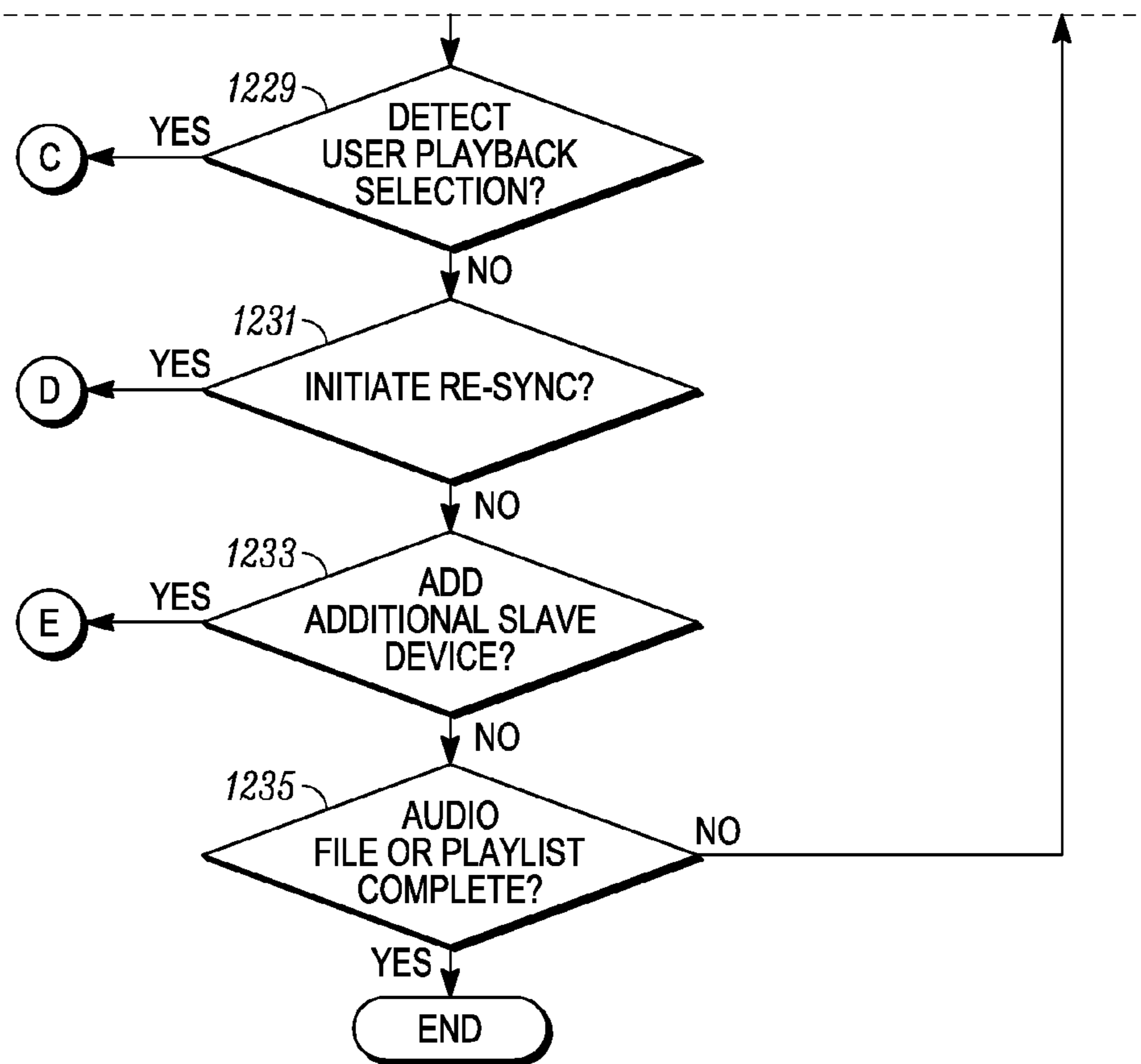


FIG. 12B

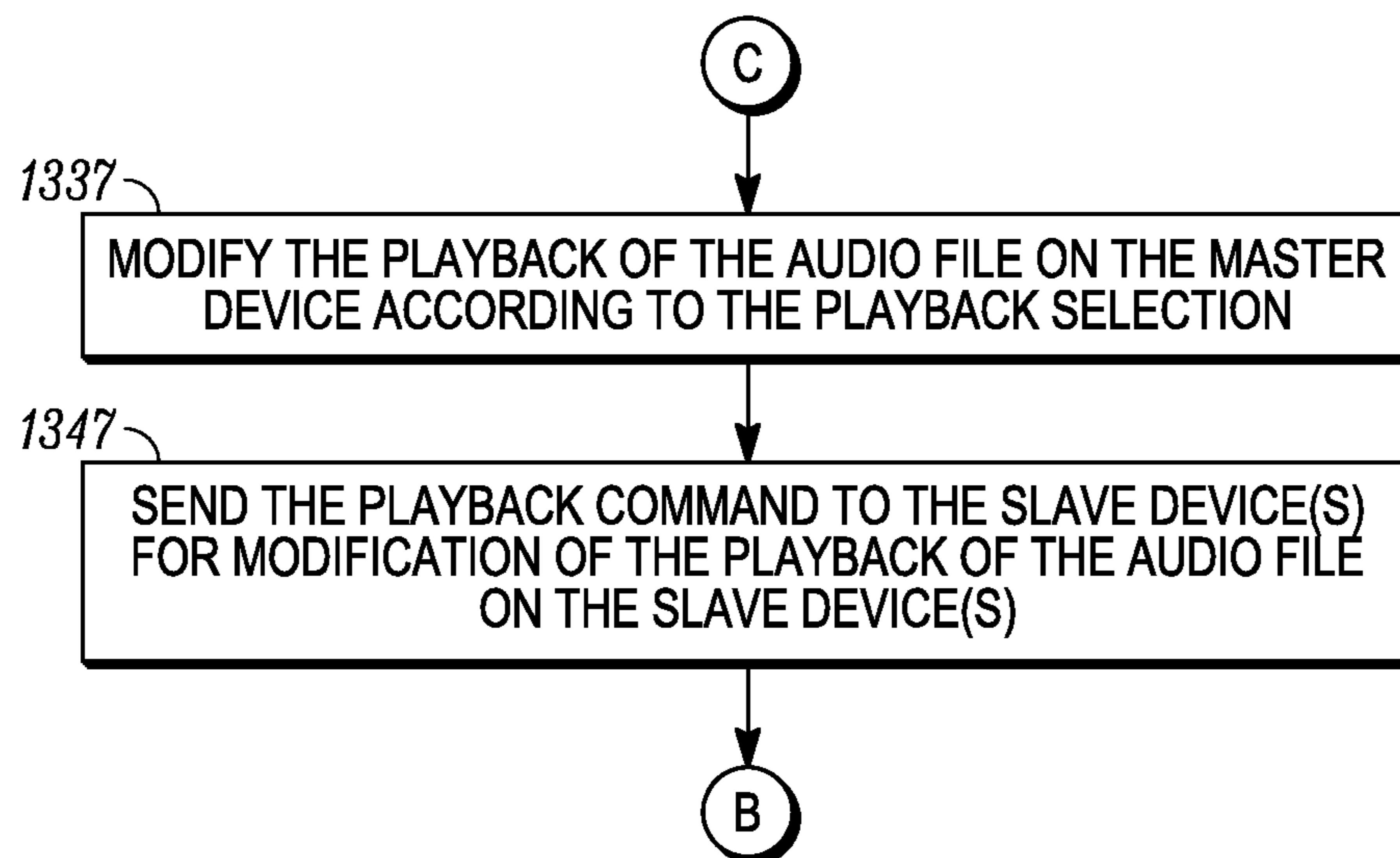


FIG. 13

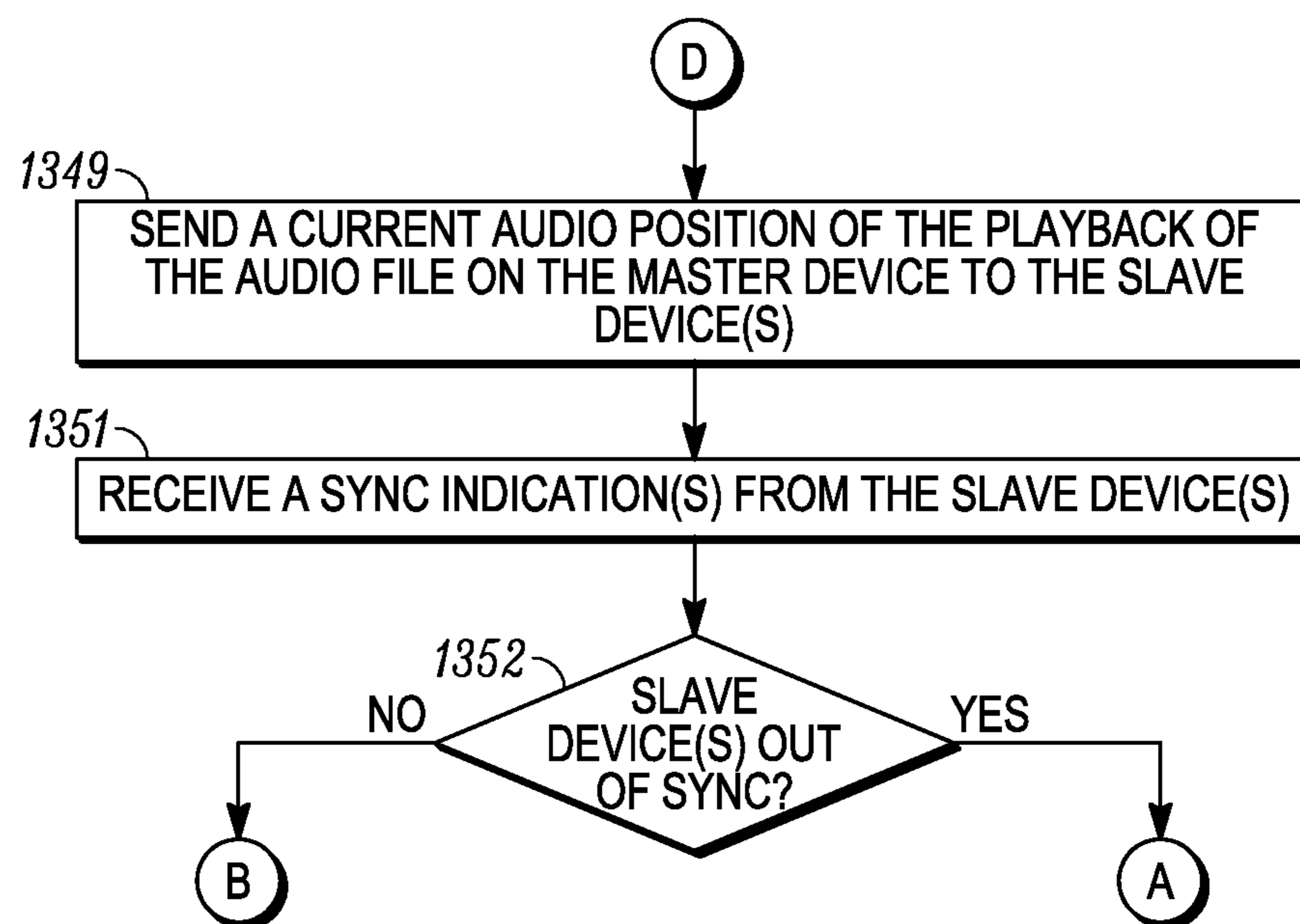


FIG. 14



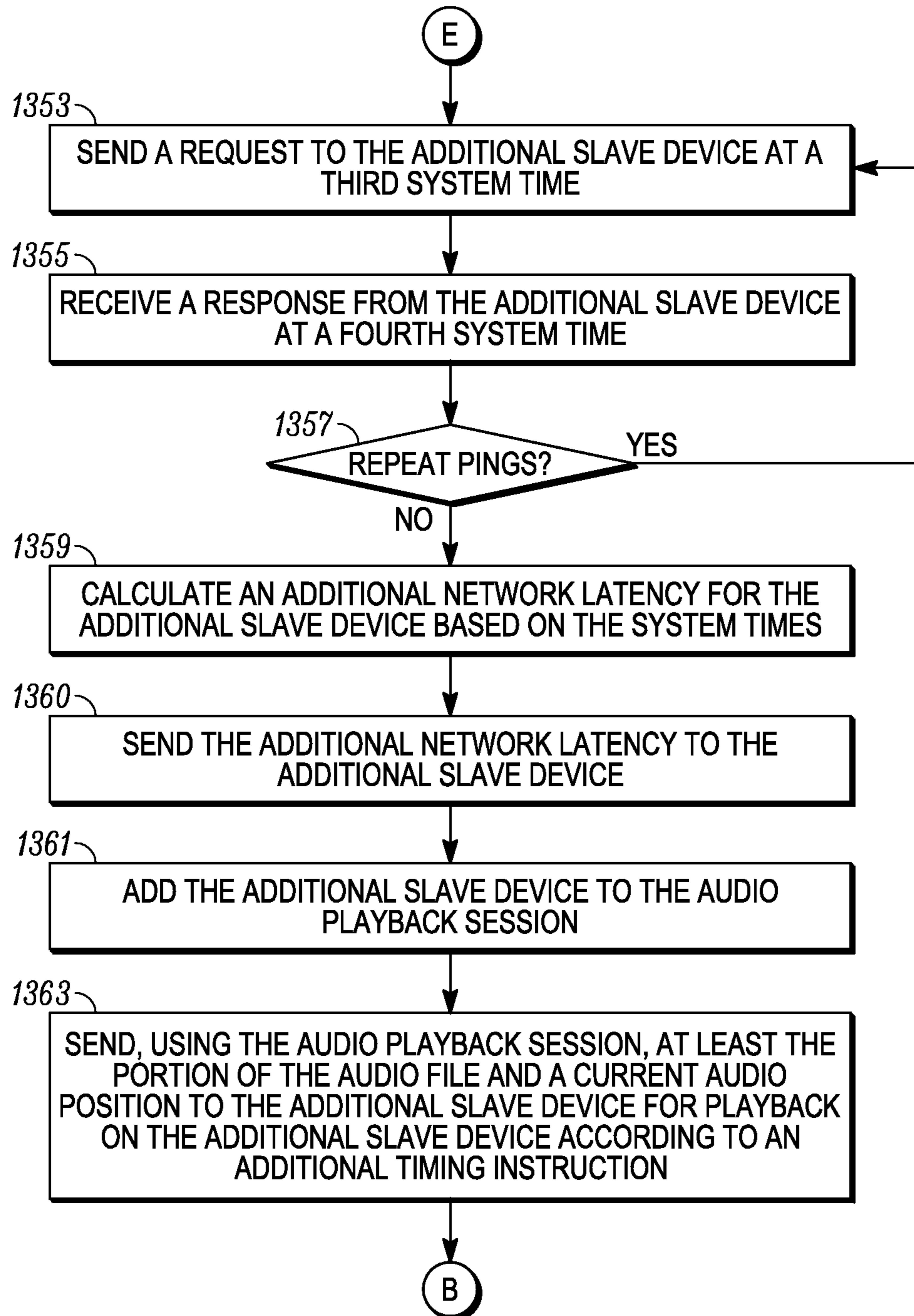


FIG. 15

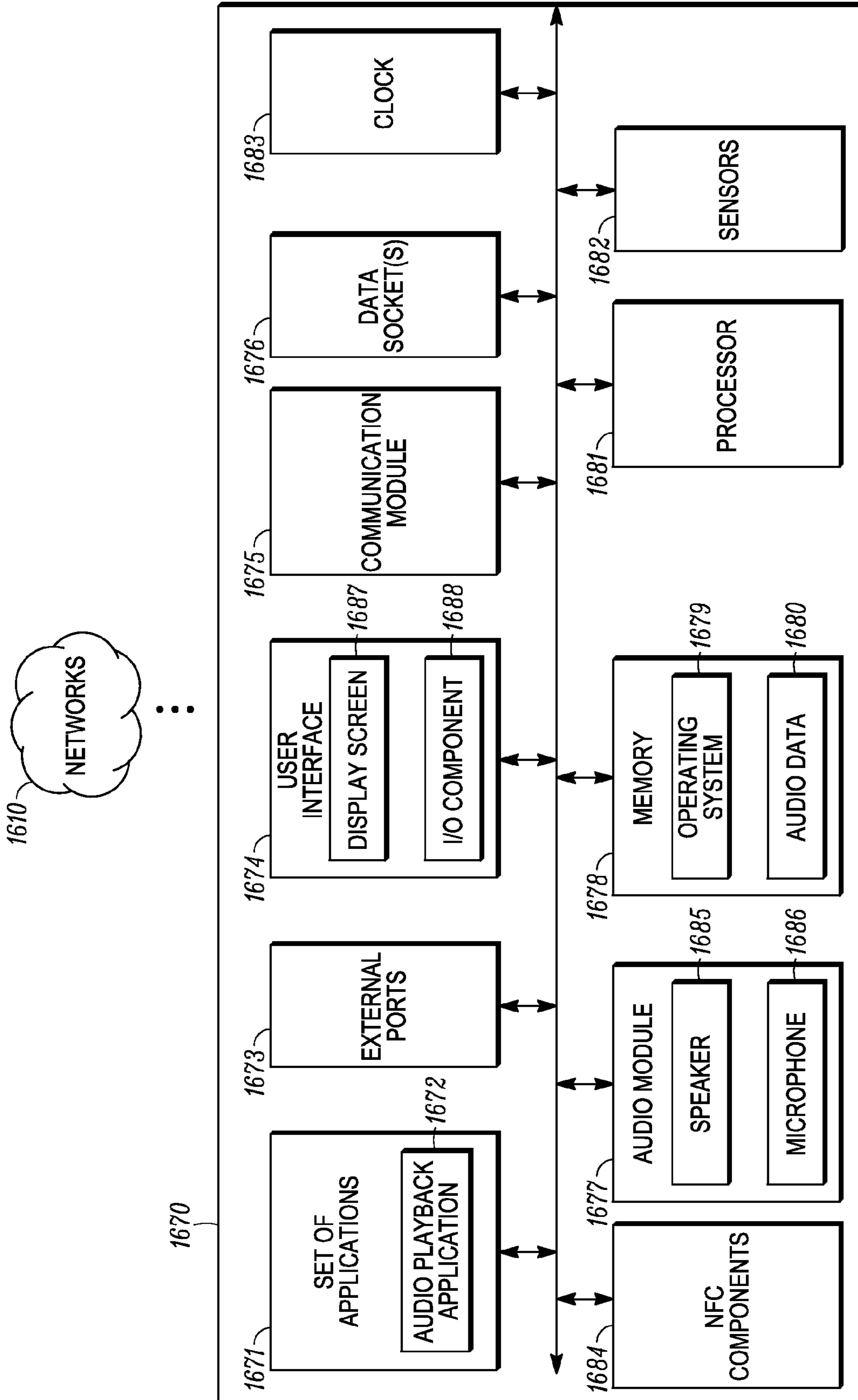


FIG. 16

## 1

## SYSTEMS AND METHODS FOR SYNCHRONIZING MULTIPLE ELECTRONIC DEVICES

### FIELD

This application generally relates to synchronizing multiple electronic devices. In particular, the application relates to platforms and techniques for determining latency time values associated with multiple electronic devices to synchronize playback of audio from the multiple electronic devices.

### BACKGROUND

Various known electronic devices support audio playback through audio components such as external speakers. For example, a user may use speakers for audio playback in situations in which the user does not have or does not wish to use headphones or earbuds. In some cases, respective users of multiple electronic devices may wish to collectively listen to a song via the respective speakers of their multiple electronic devices. The resulting combined audio from the multiple speakers may be louder than audio output from a single speaker and therefore may provide a better listening experience for the users.

Existing techniques for syncing and playing audio from multiple speakers result in inaccurate setup and, accordingly, out-of-sync audio playback. In particular, the existing techniques do not account for various timing offsets, latency buffering, and re-connecting attempts. Additionally, the existing techniques do not adequately handle packets of audio data to facilitate the audio playback from the multiple devices. Accordingly, there is an opportunity to implement embodiments for syncing multiple electronic devices such that audio playback from the multiple electronic devices is synchronized. Additionally, there is an opportunity to implement embodiments for exchanging data parameters among multiple electronic devices to initiate audio playback and accurately synchronize the audio playback based on the data parameters.

### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, together with the detailed description below, are incorporated in and form part of the specification, and serve to further illustrate embodiments of concepts that include the claimed embodiments, and explain various principles and advantages of those embodiments.

FIG. 1 depicts an example representation of electronic devices capable of group audio playback in accordance with some embodiments.

FIG. 2 depicts an example diagram associated with initiating audio playback on multiple electronic devices in accordance with some embodiments.

FIG. 3 depicts an example diagram associated with multiple electronic devices switching audio playback roles in accordance with some embodiments.

FIG. 4 depicts an example diagram associated with adding an electronic device to an audio playback session in accordance with some embodiments.

FIG. 5 depicts an example diagram associated with synchronizing multiple electronic devices in accordance with some embodiments.

## 2

FIGS. 6-11 depict example interfaces associated with an audio playback application in accordance with some embodiments.

FIGS. 12A and 12B depict a flow diagram of initiating audio playback on multiple electronic devices in accordance with some embodiments.

FIG. 13 depicts a flow diagram of initiating modifying audio playback on multiple electronic devices in accordance with some embodiments.

FIG. 14 depicts a flow diagram of syncing audio playback on multiple devices in accordance with some embodiments.

FIG. 15 depicts a flow diagram of adding an electronic device to an audio playback session in accordance with some embodiments.

FIG. 16 is a block diagram of an electronic device in accordance with some embodiments.

### DETAILED DESCRIPTION

Embodiments as detailed herein enable multiple electronic devices to play or output audio via their speakers with reduced or eliminated synchronization issues. In this way, one or more users of the electronic devices can listen to the audio without experiencing delays or offsets in the audio output timing of the respective electronic devices. At a given time, one of the electronic devices is deemed a master device and the remaining one or more electronic devices are deemed slave devices.

According to some embodiments, the master device can detect one or more slave devices via near field communication (NFC) and connect to the slave devices via a wireless connection, such as Wi-Fi Direct or another wireless connection. The master device can query the slave devices and calculate a network latency time value for each slave device based on a time when the master device receives a response from that slave device. The master device can send the calculated network latency time value to each slave device for storage on each slave device. The master device can establish an audio playback session with the slave devices and send portions of an audio file as well as a playback timing instruction to each slave device, where the playback timing instruction can include a current system time of the master device. Each slave device can calculate a system clock offset value according to the current system time of the master device, the respective system time of each slave device, and the calculated network latency time value. According to embodiments, the master device can initiate playback of the audio file and the slave devices can initiate playback of the audio file according to their playback timing instructions as well as their calculated system clock offset values such that the audio playback can occur on both the master and slave devices with little or no delay issues.

In some embodiments, the master device and the slave devices can refine any sync discrepancies via manual input from a user or via automatic calculations based on hardware latency, elapsed time discrepancies, and/or playback of various audio sync data. Further, a master device or a slave device can modify the audio playback according to pause, fast forward, rewind, skip, and other playback commands received via a user interface and, in some cases, the slave device can switch roles with the master device according to various commands initiated from the slave device. In further embodiments, an additional slave device can join an existing audio session between a master device and one or more slave devices.

The embodiments as discussed herein offer a benefit to users by effectively and efficiently reducing or eliminating

sync issues that can be experienced during “group audio” sessions. Instead of users having to manually sync audio playback from multiple devices, the embodiments offer techniques to sync electronic devices based on hardware and software latencies and network latencies and to issue playback instructions based on the syncing, thus improving playback timing. The embodiments further offer the benefit of manually and automatically adjusting timing parameters to improve synchronization accuracy. The users can therefore leverage the speakers from multiple device speakers to produce a more desirable listening experience, as the speakers of a single electronic device may not be capable of producing a preferred level of sound. Delays among the group of devices of less than 100 milliseconds, compared to another device, are acceptable under some circumstances, depending on the frequency (frequency response), amplitude (dynamic range), tempo, and other acoustic features of the audio recording. The manual and/or automatic adjustment of timing parameters may either reduce delays to improve absolute timing synchronization or increase delays to improve psychoacoustic perception of sound localization (e.g., left and right channel separation or auditory scene creation) or other desired effects (e.g., reverb and delay).

It should be noted that the disclosures in this specification are made and intended to be interpreted to their broadest extent under the patent laws, and that while the systems and methods described herein may be employed broadly in numerous applications and embodiments consistent with their capabilities, nothing in this disclosure is intended to teach, suggest, condone, or imply noncompliance with any other law or regulation that may be applicable to certain usages or implementations of the systems and methods. For example, while the systems and methods disclosed herein are technologically capable of copying, transmitting, and playback of media files and associated artwork or other metadata, such capabilities and functionalities should not be construed as a teaching, recommending, or suggesting use of such capabilities and functionalities in a manner that does not comply with all applicable existing laws and regulations, including without limitation, applicable national, state, and common law privacy or copyright laws. Again, such broad disclosure is intended for compliance with and interpretation under the patent laws and regulations.

The electronic devices as described herein utilize system clocks that facilitate the functionalities according to a “relative timing” approach, whereby timing commands are programmed and latencies are calculated based on the relative differences in clock readings and delays calculated therefrom. For example, a master electronic device can command a slave device to start playing an audio file 1.15 seconds after receipt. However, it should be appreciated that the electronic devices can similarly facilitate the functionalities according to an “absolute timing” approach, whereby timing commands are programmed and latencies are calculated based on readings from a common clock. For example, a master device and a slave device can access the same clock, and the master device can command the slave device to start playing an audio file at 12:59:59.55 pm.

FIG. 1 is an example representation 100 of electronic devices capable of group audio playback. As shown in FIG. 1, a group of users 101, 102, 103 having respective electronic devices 104, 105, 106 can be located within a proximity 107 to each other, as represented by the dashed circle. This proximity 107 may be bounded by the wireless communication range of at least one of the devices 104, 105, 106. Each of the electronic devices 104, 105, 106 may be, for example, a handheld wireless device, such as a mobile phone, a Personal

Digital Assistant (PDA), a smart phone, a tablet or laptop computer, a multimedia player, an MP3 player, a digital broadcast receiver, a remote controller, or any other electronic apparatus. Although the embodiments envision the electronic devices 104, 105, 106 as portable and hand-held, it should be appreciated that other non-portable devices are envisioned. Each of the electronic devices 104, 105, 106 can optionally exchange information with a network 110, such as a cellular network, such as in cases in which one or more of the electronic devices 104, 105, 106 retrieves audio data from the network 110.

According to embodiments, the electronic devices 104, 105, 106 can connect to and communicate with each other via various wireless connections. For example, the electronic devices 104, 105, 106 can initially detect each other via near field communication (NFC). In particular, respective NFC components of the electronic devices 104, 105, 106 such as NFC tags and/or NFC chips can detect proximity with other NFC components and establish NFC connections using unique identifications. The electronic devices 104, 105, 106 can also include communication modules that enable the electronic devices 104, 105, 106 to wirelessly connect to each other, such as via a Wi-Fi Direct connection or a Wi-Fi connection.

In operation, the users 101, 102, 103 may wish to establish a “group play” of audio whereby external speakers of their respective electronic devices 104, 105, 106 are leveraged to simultaneously output audio. According to embodiments, the electronic devices 104, 105, 106 are configured to sync with each other based on network and/or hardware and software latencies, whereby one of the electronic devices 104, 105, 106 is deemed the master device and the remaining electronic devices are deemed slave devices. For purposes of explanation, assume that the electronic device 104 is the master device and the electronic devices 105, 106 are the slave devices. The master electronic device 104 can facilitate a syncing technique with the slave electronic devices 105, 106 to determining timing for audio playback. Further, the master electronic device 104 can select an audio file and send portions of the audio file to the slave electronic devices 105, 106 via the wireless connections. The master electronic device 104 can initiate playback of the audio file based on the syncing information and can send playback instructions for the audio file to the slave electronic devices 105, 106, where the playback instructions are also based on the syncing information.

In some embodiments, the electronic devices 104, 105, 106 can switch roles whereby a slave device can become a master device and vice-versa. For example, a slave device can select a new audio playlist which triggers a request to a master device for a role change. In other embodiments, an additional user 108 may wish to join his or her electronic device 109 to the audio playback session among the other electronic devices 104, 105, 106. When the additional electronic device 109 is within the proximity 107, the master device of the audio playback session can connect to the electronic device 109, facilitate the syncing technique to establish proper timing with the electronic device 109, and send appropriate audio file portions and playback timing instructions such that the electronic device 109 can output the audio file in sync with the other electronic devices 104, 105, 106. In some embodiments the additional electronic device 109 is invited to the group audio session through an NFC communication with one of the devices 104, 105, 106 already in the group audio session.

Referring to FIG. 2, depicted is an example diagram 200 associated with initiating audio playback in a master device 204 and a slave device 205. Although FIG. 2 depicts only the

master device **204** and one slave device **205**, it should be appreciated that the functionalities of the diagram **200** can be implemented with multiple slave devices. The audio playback initiating can begin with an NFC pairing whereby the master device **204** sends **212** a unique ID to the slave device **205** via an NFC transfer and triggers **214** an NFC connection complete response. In embodiments, the slave device **205** can send an NFC connection success message to the master device **204** to acknowledge reception of the unique ID.

The master device **204** can initiate **216** a wireless connection broadcast with the slave device **205** and the slave device **205** can connect **218** to the master device **204** via the wireless connection. In some embodiments, the master device **204** can broadcast a Wi-Fi Direct service containing the unique ID of the master device **204** as well as service types unique to the audio initiation so as not to collide with other Wi-Fi Direct services. Further, in some embodiments, the slave device **205** can broadcast its service as well as attempt to discover services and, when the slave device **205** finds a service that matches the unique ID of the master device **204**, the slave device **205** can stop broadcasting its service and attempt to connect to the service of the master device **204**. The master device **204** and the slave device **205** can further receive information about the connection (e.g., the IP address of the master device **204**) so that the roles (i.e., which device is the master and which device is the slave) can be established. Further, the master device **204** and the slave device **205** can initiate or open any threads through one or more sockets and/or via TCP connections to facilitate data transfer. It should be appreciated that other wireless connections between the master device **204** and the slave device **205** are envisioned, such as a Wi-Fi connection.

Referring to FIG. 2, the master device **204** can send **220** a series of network latency pings to the slave device **205**. Each of the pings can include a current system clock time as recorded by the master device **204**. In some embodiments, the current system clock time can correspond to an elapsed time relative to how long the master device **204** has been powered on. Upon receipt of the network latency ping, the slave device **205** can compare the received system clock time from the master to its current clock time to determine a difference in clock times and save this difference to a memory. Further, the slave device **205** can send **222** a series of receipt pings to the master device **204** and the master device **204** can calculate **224** a network latency value based on a timing associated with the receipt of the receipt pings. In particular, the master device **204** can record a second system time corresponding to the time that the master device **204** receives the receipt ping and can calculate a round-trip network latency value based on the difference between the first system time and the second system time.

Additionally, the master device **204** can estimate the one-way network latency value as half the difference between the first system time and the second system time, or according to other calculations. In some further embodiments, the master device **204** can calculate the one-way network latency value based on averaging multiple network latency pings. According to embodiments, the master device **204** can send **225** the estimated one-way network latency value to the slave device **205**.

The slave device **205** can calculate **226** a system clock offset value based on subtracting the estimated one-way network latency value received from the master device **204** from the difference in master and slave clock times previous saved by the slave device **205**. According to some embodiments, the slave device **205** can optionally open **227** a command pipe

with the master device **204** over which the slave device **205** can send various commands, for example commands to control playback of an audio file.

The master device **204** can select an audio file for playback and send **228** an “audio file selected” command to the slave device **205**. In some embodiments, a user can select the audio file via a user interface of the master device **204**. Further, the master device **204** can initiate a corresponding audio playback application to facilitate the audio playback and playback commands associated therewith. It should be appreciated that the audio file can be saved locally on the master device **204** or can be retrieved from a remote server via a network connection (see FIG. 1 element **110**). For example, the master device **204** can “stream” an audio file from a remote server. The master device **204** and the slave device **205** can establish **230** an audio playback session via, for example, a dedicated connection using a thread command. The master device **204** can send **232** a portion of the audio file to the slave device **205** along with a timing instruction using the audio playback session, whereby the timing instruction can include the current system time for the master device **204**. In some embodiments, the timing instruction can include a specified time to play, a playback position to seek, or a current playback position playing. For example, the timing command can instruct the slave device **205** to start playing the portion of the audio file in 0.75 seconds, to start playing the portion of the audio file 1.30 seconds after receipt, to start playing the audio file at an elapsed time of 00:25.02, or according to other relative timing parameters. In some embodiments, the slave device **205** can notify a user after the portion of the audio file is received.

The master device **204** can initiate **234** playback of the audio file and the slave device **205** can initiate **236** playback of the audio file according to the timing instruction as well as the system clock offset value calculated in **226**. Accordingly, the respective audio output from the master device **204** and the slave device **205** can be synced based on the amount of time it takes for the master device **204** to send the audio file to the slave device **205** (i.e., the network latency or a modification thereof). The master device **204** can send **238** additional portion(s) of the audio file to the slave device **205** using the audio playback session, whereby the master device **204** and the slave device **205** can play the additional portion(s) as previously described with reference to **234**, **236**. The previously-sent timing instruction **232** may be applied to the additional portions of the audio file. Consequently, the playback of the audio file on the master device **204** and the slave device **205** can be continuous and uninterrupted.

In some embodiments, the master device **204** can optionally confirm **240** playback synchronization of the audio file at the slave device **205**. In particular, the master device **204** can send an elapsed playback time of the audio file to the slave device **205** and the slave device **205** can compare the master elapsed playback time to its own elapsed playback time. If the difference in elapsed playback times exceeds a threshold amount (whereby the threshold amount is based on a predetermined threshold amount as well as the network latency value and/or timing instruction), any slave device **205** that is out of sync can send an indication **241** to the master device **204** that the playback is out of sync. If the playback is out of sync, this may trigger a re-performance of network latency estimations **220**, **222**, **224**, **225**, **226** with the out-of-sync slave device **205**. The master device **204** and/or the out-of-sync slave device **205** can adjust the playback of the audio file to account for the discrepancy. For example, the master

device **204** can delay its playback or can instruct the slave device **205** to increase its playback rate or skip to another portion of the audio file.

In some embodiments, the master device **204** can optionally send **242** a playback command as well as an optional timing instruction to the slave device. For example, a user of the master device **204** can select to pause, to fast forward or rewind the audio file (e.g., by dragging along a time line corresponding to the audio file playback and then releasing), or to skip to another audio file or another playlist. For further example, a user of the slave device **205** can make similar playback selections and the slave device **205** can send the selections as requests to the master device **204** to have the master device **204** modify the playback accordingly. The master device **204** can perform **243** the playback command. The slave device **205** can perform the playback command in compliance with the timing instruction and the system clock offset value, if applicable.

In some embodiments, the playback commands (e.g., fast forward, rewind, etc. as implemented by moving an indicator along a time line) can be a variant of confirming the playback synchronization per step **240**. For example, assume that one second ago, 1:37 of the audio playback of a certain song had elapsed on the master device **204**, and the user has adjusted a slider bar so that the audio playback is now at 2:00. Then, the master device **204** can send a confirmation **240** sync request to the slave device **205** indicating that the audio playback is at 2:00. The slave device **205** can receive the confirmation sync request and indicate **241** that the slave device **205** is “out of sync.” Further, the slave device **205** can jump to the 2:00 mark of audio playback (plus any compensation for network delay and optionally acoustic delay), and the master device **204** and the slave device **205** can re-perform their network latency calculations **220, 222, 224, 225, 226**.

FIG. **3** depicts an example diagram **300** associated with a master device **304** and a slave device **305** switching roles. Although FIG. **3** depicts only the master device **304** and one slave device **305**, it should be appreciated that the functionalities of the diagram **300** can be implemented with multiple slave devices. Further, it can be assumed that the master device **304** and the slave device **305** have established a wireless connection and an audio playback session, as previously described with respect to FIG. **2**. According to embodiments, the master device **304** and the slave device **305** can offer the same playback commands (see FIGS. **6** and **7**), however for the slave device **305** to become the new master device, a user of the slave device **305** independently selects a new audio file, playlist, or the like.

As shown in FIG. **3**, the master device **304** can initiate **334** playback of an audio file (similar to **234** as described with respect to FIG. **2**) and the slave device **305** can initiate **336** playback of the audio file according to a timing instruction as well as the system clock offset value (similar to **236** as described with respect to FIG. **2**).

The slave device **305** can detect **344** a selection of an additional audio file, where the selection triggers a role change wherein the slave device **305** can become the new master device and the master device **304** can become the new slave device. For example, the selection of the additional audio file can be an audio file or playlist of audio files stored on the slave device **305** or otherwise accessible by the slave device **305**. The slave device **305** can send **346** a request to switch roles to the master device **304** and the master device **304** can send **348** a notification of the role switch to the slave device **305**. Upon receipt of the notification, the slave device **305** (now the new master device) can calculate **350** a new network latency value and a new system clock offset value

with the master device **304** (now the new slave device) via a series of network latency pings and calculations, similar to **220, 222, 224, 225, 226** as discussed with respect to FIG. **2**.

The new master device **305** can establish **330** an additional audio playback session with the new slave device **304**, similar to **230** as discussed with respect to FIG. **2**. The new master device **305** can send **332** a portion of the additional audio file to the new slave device as well as a new timing instruction using the additional audio playback session, whereby the new timing instruction can include a current system time of the new master device **305**. The new master device **305** can initiate **334** playback of the additional audio file and the new slave device **304** can initiate **336** playback of the additional audio file according to the new timing instruction as well as the new system clock offset value resulting from **350**, similar to **234** and **236** as discussed with respect to FIG. **2**. Thus the old slave device **305** becomes the new master device whereby the playback commands **242**, the sync confirmations **240, 241**, and the additional audio file portions transmittals **238** are still active, but now for the new master device.

FIG. **4** depicts an example diagram **400** associated with a new slave device **409** joining an existing audio session between a master device **404** and a slave device **405**. It can be assumed that the master device **404** and the slave device **405** have established a wireless connection and an audio playback session, as previously described with respect to FIG. **2**. As shown in FIG. **4**, the master device **404** can initiate **434** playback of an audio file (similar to **234** as described with respect to FIG. **2**) and the slave device **405** can initiate **436** playback of the audio file according to a timing instruction (similar to **236** as described with respect to FIG. **2**).

When within the proximity **107**, the new slave device **409** can send **452** a request to the master device **404** to join the audio playback session between the master device **404** and the slave device **405**. The master device **404** can calculate **454** a new network latency value and a new system clock offset value with the slave device **406** via a series of network latency pings and calculations, similar to **220, 222, 224, 225, 226** as discussed with respect to FIG. **2**. The master device **404** can add **456** the slave device **409** to the audio playback session and can send **432** a portion of the audio file, a current elapsed time of the audio file playback, and an additional timing instruction to the slave device **406** using the audio playback session, whereby the additional timing instruction can include the current system time for the master device **404**. The slave device **409** can initiate **436** playback of the audio file at the current elapsed time according to the additional timing instruction as well as the new system clock offset value. Meanwhile the master device **404** may initiate **234** playback of that portion of audio file, and the first slave device **405** may initiate **236** playback of that portion of the audio file according to its timing instruction and system clock offset value.

As shown in FIG. **4**, the master device **404** can send **438, 439** an additional portion of the audio file to the slave device **405** and the slave device **409** for playback on the respective slave devices **405, 406**, as discussed with respect to **238** of FIG. **2**. In some embodiments, the master device **404** can send an additional timing instruction associated with the additional portion. The master device **404** can optionally confirm playback sync **440, 441**, of the audio file with the slave device **405** and the slave device **406**, as discussed with respect to **240, 241** of FIG. **2**. In addition, the master device **404** can optionally modify **442, 443** playback of the audio file based on playback commands received by the master device **404**, the slave device **405**, and/or the slave device **409**, as discussed with respect to **242, 243, 244** of FIG. **2**. For example, a user of the slave device **409** can request to pause playback of the audio

file, whereby the slave device **409** can send a pause command request to the master device **404** and the master device can pause its own playback as well as send a pause command to the slave devices **405**, **409** to pause playback.

The embodiments as discussed herein can account for an audio latency for in-device hardware and software computing delays (a computing audio latency) plus an acoustic “through air” delay, which excludes estimated network latency delay. This audio latency can be determined using audio sync data playback and at least one microphone of one of the devices. In some embodiments, when two devices initially form a group audio session, the NFC pairing can trigger a wireless connection and an initial network delay measurement as well as trigger an audio sync measurement process to determine an audio latency delay between the two devices. The audio sync measurement process, which can initiate while the devices are close to each other (e.g., within a short NFC range), can utilize the initial network delay ping results to instruct playback of orthogonal audio sync data at the same time (based on network delay compensation) by both devices. The orthogonal audio sync data waveforms may be designed to include a wide frequency response and create a pleasant audio-feedback sound so that users recognize that a new device has joined the group audio session (e.g., an up-chirp played by one device and a down-chirp played by another device). Alternately, the audio sync data may sound like different types of noise (e.g., white noise played by one device and brown noise played by another device). Other types of orthogonal audio sync data may also be used.

The master device can cross-correlate the audio from both devices as received at its microphone and can determine the differences between the audio latency delay for the master device and the slave device. The master device can give the slave device a compensation value for the audio latency delay so that the slave device can make its own adjustments during playback, or the master device can use the network delay and the audio latency delay difference values to calculate updated timing instructions for audio playback. Alternately or additionally, the slave device may independently cross-correlate the audio from both devices as received at its microphone and determine the audio latency delay for itself. The slave could then report its determined audio latency delay difference to the master device as well as report its device model (e.g., Motorola DROID RAZR MARX).

It should be appreciated that additional devices may join the group audio session via the NFC connection. The NFC touch can be with any device currently in the group audio session (e.g., either the master device or a slave device). The NFC detection can trigger a wireless connection and initial network delay measurement and can trigger an audio sync measurement process between the additional device and the “inviting” device that is already in the group audio session as described previously. In case additional devices join via a series of slave devices (e.g., a daisy chain of additional devices), a table of device models may be created by the master device and used to normalize the hardware and software delay plus the acoustic “through air” delay difference values on the assumption that devices of the same model would have similar hardware and software delays plus similar acoustic “through air” delays.

FIG. **5** depicts an example diagram **500** associated with a master device **504** and one slave device **505** facilitating the audio sync measurement process to measure audio latency delay, which includes hardware and software plus acoustic “through the air” delays and does not include network latency. Although FIG. **5** depicts only the master device **504** and the slave device **505**, it should be appreciated that the function-

alities of the diagram **500** can be implemented with multiple slave devices. Further, it can be assumed that the master device **504** and the slave device **505** have established a wireless connection or otherwise that the master device **504** has initiated the wireless connection broadcast. As shown in FIG. **5**, the master device **504** can establish **530** an audio playback session with the slave device **505**, similar to **230** as described with respect to FIG. **2**. To perform the audio latency measurement, the master device **504** can send **558** an instruction to play audio sync data as well as a corresponding timing instruction indicating a specified time to the slave device **505** using the audio playback session. In some embodiments, the audio sync data can be a chirp (such as an up-chirp or a down-chirp) that can be used to gauge device hardware, device software, and “through the air” audio latencies (i.e., not network latencies) and/or frequency response measurements.

The master device **504** can initiate **560** playback of the audio sync data at the specified time after the master device **504** wirelessly connects (e.g., via an NFC pairing) to the slave device **505**, and the slave device **505** can initiate **562** playback of the audio sync data at the specified time after the master device **504** connects to the slave device **505**. The master device **504** can leverage an audio input component (e.g., a microphone) to detect **564** audio from playback of the audio sync data on the master device **504** and the slave device **505**. Further, the master device **504** can calculate **566** an audio latency time value from the detected audio using, for example, a cross-correlation function. In particular, the audio latency time value can reflect any computing audio latency plus acoustic “through the air” delay in the respective audio sync data playbacks on the master device **504** and the slave device **505**. In some embodiments, such as if the audio sync data is a chirp, the master device **504** can calculate new frequency values based on respective frequency response measurements of the master device **504** and/or the slave device **505**.

Although not depicted in FIG. **5**, it should be appreciated that the slave device **505** can detect the audio sync data playbacks (for example via a microphone of the slave device **505**), independently calculate an audio latency time value, and adjust its audio playback timing accordingly. The master device **504** can send **568** to the slave device **505** a playback modification instruction based on the slave’s calculated audio latency time value, the master’s calculated audio latency time value, or a combination of the master’s and the slave’s calculated audio latency time value, and the slave device **505** can modify its playback of audio files accordingly.

In some embodiments, audio playback on the group of devices can be modified based on the detected audio frequency response and the dynamic range of each device. For example, one device may have a good bass frequency response and another device may have a good treble frequency response. The comparative “good/better” frequency response of each device’s audio speakers may be detected during the audio sync measurement process. As a result, the master device may provide the audio data and timing instructions as well as frequency playback instructions and/or volume instructions.

FIGS. **6-11** depict example interfaces associated with an audio playback application in accordance with some embodiments. According to embodiments, each of the master and the slave device(s) can execute the audio playback application and display the example interfaces on respective user interfaces. FIG. **6** depicts an example interface **600** that a master device can display on a user interface. The interface **600** indicates an audio file that the master device can play, and can

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indicate metadata associated with the audio file such as song title **605**, artist **608**, album artwork **610**, total file play time **620**, elapsed file play time **625**, and/or other data. The interface **600** further includes various playback selections **690** that correspond to playback commands that can be selected by a user of the master device. For example as shown in FIG. **6**, the playback selections **690** include a previous track selection **692**, a pause (or play) selection **694**, a next track selection **696**, and a repeat selection **698**. The interface **600** also includes a re-sync selection **699** that, when selected, causes the master device to issue a command to each slave device to send respective current playback locations. The interface **600** additionally indicates a progress of the audio track playback **625** and enables the user to navigate to other playback points of the audio track.

Referring to FIG. **7**, depicted is an example interface **700** that a slave device can display on a user interface. The interface **700** includes the same or similar content as the interface **600**, including playback selections **790** that mirror the playback selections **690** and enable a user of the slave device to request control playback of the audio file(s). Accordingly, the users of slave devices can view the same currently playing content and information **705**, **708**, **710**, **720**, **725** as the user of the master device, as well as effectively control playback **792**, **794**, **796**, **798** of the audio files in a similar manner as the user of the master device. The interface **700** also includes a re-sync selection **799** that, when selected, causes the slave device and its master device to repeat the network latency pings and system clock offset value calculations. Although not depicted in FIGS. **6** and **7**, it should be appreciated that other playback selections or controls are envisioned.

Referring to FIG. **8**, depicted is an example interface **800** that a slave device and/or a master device can display on a user interface. The interface **800** enables a user to browse and/or select various albums that are available for playback. It should be appreciated that various gestures, such as scrolling, are supported to enable the user to navigate through the interface **800**. If a user selects one of the albums of the interface **800**, the slave device and/or the master device can display details for the selected album, for example as shown in an interface **900** of FIG. **9**. Referring to FIG. **9**, the interface **900** displays details for the album "Album A" by Artist A. The interface **900** includes selections for the songs on the album "Album A" and enables the user to select one or more of the songs for playback. For example, referring to FIG. **10**, an interface **1000** depicts a playback of the song "Song A1" that the user has selected from the album details. As shown in FIG. **10**, the interface **1000** includes playback selections **1090** that enable the user to control playback of the song and to navigate to other songs. It should be appreciated that a slave device and/or a master device can display the interface **1000**.

Referring to FIG. **11**, depicted is a detailed interface **1100** capable of being displayed by a slave device and/or a master device. The interface **1110** includes an audio latency adjuster **1192** that enables the user of the slave device and/or the master device to adjust playback timing for the respective device. According to embodiments, the device can have an audio latency time value that represents an elapsed time for audio to propagate through the device from its controller module or processor to the output component or speaker as detected by a microphone of the device, and the audio latency adjuster **1192** enables the user to add or subtract time from this value to sync playback of the audio.

In some cases as shown in FIG. **11**, the audio latency adjuster **1192** can indicate the calculated audio latency time value for the device (as shown: 79 ms) as the center of a sliding adjuster **1196** with a selector **1197** overlaid thereon.

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The user of the device can adjust the selector **1197** to add (e.g., by sliding to the right) or subtract (e.g., by sliding to the left) time that the device can add to or subtract from any playback timing instructions. For example, if the user slides the selector **1197** to the right side of the sliding adjuster **1196**, the device can add a corresponding amount of milliseconds to the playback timing instructions, which can be shown as an updated number in the text box **1198**. As an alternate adjustment, a user may type a number directly in the text box **1198**. It should be appreciated that the master device can, according to any adjustments on the audio latency adjuster **1192**, adjust its own playback timing or can send instructions to the slave device to adjust its playback timing. Further, it should be appreciated that the slave device can adjust its own playback timing according to any adjustments on its own audio latency adjuster **1192**. Although the audio latency adjuster **1192** as shown in FIG. **11** has a range of 100 ms with example values, it should be appreciated that other ranges and values are envisioned. In some embodiments, the user can use the audio latency adjuster **1192** adjustments to produce a "bigger" sound or to introduce a reverb effect.

FIG. **12** is a flowchart of a method **1200** for a master electronic device to facilitate audio playback on multiple electronic devices. The method **1200** begins with the master device establishing **1211** a wireless connection between itself and one or more slave devices. According to embodiments, the wireless connection can be established via an NFC pairing and/or a Wi-Fi Direct or other wireless connection. Because the master device is in close proximity to the one or more slave devices, the master device can optionally test **1212** for any hardware and software latency or acoustic delay via audio received by a microphone of the master device, as discussed herein with respect to measuring an acoustic latency time value. The master device can send **1213** a network latency request along with its current system time to the slave device(s) at a first system time. According to embodiments, the slave device(s) can store the current system time of the master device. The master device can receive **1215** a response from the slave device(s) at a second system time. In embodiments, the response can include a confirmation that the slave device(s) received the request. The master device can determine **1217** whether to repeat the network latency requests. If the master device determines to repeat the network latency requests ("YES"), processing can return to **1213**. If the master device determines to not repeat the network latency requests ("NO"), the master device can calculate **1219** a one-way network latency for the slave device(s) based on the system times. In some embodiments in which there are multiple slave devices, the master device can determine different network latencies for respective slave devices based on the responses from the multiple slave devices and optionally add acoustic latencies. In embodiments, the master device can send **1220** the additional one-way network latency to the slave device(s), which the slave device(s) can use along with the stored system time for the master device and its own system time to calculate a system clock offset value(s). In embodiments, the master device can send respective network latencies to respective slave devices to eliminate lag from the system clock offset value calculation performed by the slave devices.

The master device can select **1221** an audio file. In some cases, a user of the master device can select the audio file via a user interface. The master device can establish **1223** an audio playback session with the slave device(s) using the wireless connection. The master device can send **1225**, using the audio playback session, at least a portion of the audio file to the slave device(s) for playback on the slave device(s) according to a timing instruction that can include a current



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system time of the master device. According to embodiments, the slave device(s) can use the current system time of the master device along with the previously-calculated system clock offset value to schedule or initiate playback of the portion of the audio file. According to embodiments, the timing instruction can be the same for each slave device and can include a specified time to play, a playback position to seek, a current playback position playing, or the like. For example, the timing instruction can instruct the slave device to start playback of the portion of the audio file in 1.43 seconds, or 0.21 seconds after receipt, or at a playback position of 00:01.35 seconds, or according to other relative times. The master device can initiate or continue **1227** playback of the audio file. The slave device can also initiate or continue playback of the audio file according to the timing instruction as well as a calculated difference in system times of the master device and the slave device.

The master device can determine **1229** if a playback selection is detected. If a playback selection is not detected (“NO”), the master device determines **1231** if the synchronization should be confirmed. In embodiments, either the master device or the slave device(s) (or users thereof) can initiate the confirmation request. If the sync confirmation has not been initiated (“NO”), the master device determines **1233** whether to add an additional slave device, such as if an additional slave device has requested to join the audio playback session. If the master device determines that there are no additional slave devices to add (“NO”), the master device can determine **1235** whether the audio file or a playlist that includes the audio file is complete. If the audio file or the playlist is not complete (“NO”), processing can return to **1225** in which the master device can send an additional portion of the audio file to the slave device(s) or can send a portion of an additional audio file (such as an additional audio file of the playlist) to the slave device(s). If the audio file or the playlist is complete in **1235** (“YES”), processing can end, repeat, or return or proceed to any other functionality.

If the master device detects a playback selection in **1229** (“YES”), processing can proceed to “C” as detailed in FIG. **13**. In embodiments, the playback command can correspond to pause, play, rewind, fast forward, or the like, and can be detected via a user interface of the master device or as a request received from the slave device. The master device can modify **1337** the playback of the audio file according to the playback selection. Further, the master device can send **1347** the playback command to the slave device(s) for modification of the playback of the audio file on the slave device(s). For example, if the playback command is a pause command, the master device can pause its playback of the audio file and also send a command to the slave device(s) to pause its respective playback(s). In embodiments, processing can proceed to “B” (i.e., **1225** of FIG. **12**) or to any other functionality.

If the master device detects a request to confirm synchronization in **1231** (“YES”), processing can proceed to “D” as detailed in FIG. **14**. In particular, the master device can send **1349** a current audio position of the playback of the audio file to the slave device(s), along with a request to determine whether a respective slave device is out of sync. According to embodiments, the slave device(s) can compare the current audio position to its own elapsed playback position to determine whether its playback is out of sync with the playback of the master device. The master device can receive **1351** a sync indication from the slave device(s). The master device can examine the sync indication to determine **1352** if the slave device(s) is out of sync. If the slave device(s) is not out of sync (i.e., the slave device(s) is in sync) (“NO”), processing can proceed to “B” (i.e., **1225** of FIG. **12**) or to any other func-

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tionality. In contrast, if the slave device(s) is out of sync (“YES”), processing can proceed to “A” (i.e., **1213** of FIG. **12**) or to any other functionality.

If the master device determines to add an additional slave device in **1233** (“YES”), such as if the additional slave device requests to join the audio session, processing can proceed to “E” as detailed in FIG. **15**. In particular, the master device can send **1353** a network latency request containing a third system time (i.e., the current system time of the master device) to the additional slave device at the third system time. According to embodiments, the additional slave device can store the third system time. The master device can receive **1355** a response from the additional slave device at a fourth system time. In embodiments, the response can include a confirmation that the additional slave device received the request. The master device can determine **1357** whether to repeat the network latency requests. If the master device determines to repeat the network latency requests (“YES”), processing can return to **1353**. If the master device determines to not repeat the network latency requests (“NO”), the master device can calculate **1359** an additional one-way network latency for the additional slave device based on the system times. In embodiments, the master device can send **1360** the additional one-way network latency to the additional slave device, which the additional slave device can use along with the stored system time for the master device and its own system time to calculate an additional system clock offset value.

The master device can add **1361** the additional slave device to the audio playback session, such as via a socket of the additional slave device. The master device sends **1363**, using the audio playback session, at least the portion of the audio file to the additional slave device for playback on the additional slave device according to an additional timing instruction that can include a current system time of the master device. The additional slave device can use this current system time of the master device along with the previously-calculated system clock offset value to schedule or initiate playback of the portion of the audio file. According to embodiments, the additional timing instruction can include a specified time to play, a playback position to seek, a current playback position playing, or the like. In embodiments, processing can proceed to “B” (i.e., **1225** of FIG. **12**) or to any other functionality.

FIG. **16** illustrates an example electronic device **1670** in which the functionalities as discussed herein may be implemented. The electronic device **1670** can include a processor **1681** or other similar type of controller module or microcontroller, as well as a memory **1678**. The memory **1678** can store an operating system **1679** capable of facilitating the functionalities as discussed herein as well as audio data **1680** corresponding to any locally-stored audio files. The processor **1681** can interface with the memory **1678** to execute the operating system **1679** and retrieve the audio data **1680**, as well as execute a set of applications **1671** such as an audio playback application **1672** (which the memory **1678** can also store). The memory **1678** can include one or more forms of volatile and/or non-volatile, fixed and/or removable memory, such as read-only memory (ROM), electronic programmable read-only memory (EPROM), random access memory (RAM), erasable electronic programmable read-only memory (EEPROM), and/or other hard drives, flash memory, MicroSD cards, and others. The processor **1681** can further interface with a clock **1683** configured to identify and manage various system times as well as schedule actions based on the system times and/or any measured acoustic latencies.

The electronic device **1670** can further include a communication module **1675** configured to interface with the one or more external ports **1673** to communicate data via one or more networks **1610**. For example, the communication **1675** can leverage the external ports **1673** to establish TCP connec-

tions for connecting the electronic device **1670** to other electronic devices via a Wi-Fi Direct connection. According to some embodiments, the communication module **1675** can include one or more transceivers functioning in accordance with IEEE standards, 3GPP standards, or other standards, and configured to receive and transmit data via the one or more external ports **1673**. More particularly, the communication module **1675** can include one or more WWAN transceivers configured to communicate with a wide area network including one or more cell sites or base stations to communicatively connect the electronic device **1670** to additional devices or components. For example, the transceiver can receive remotely-stored audio data via the network **1610**. Further, the communication module **1670** can include one or more WLAN and/or WPAN transceivers configured to connect the electronic device **1670** to local area networks and/or personal area networks, such as a Bluetooth® network. The electronic device **1670** further includes one or more data sockets **1676** through which audio playback sessions with other devices can be established, as discussed herein.

The electronic device **1670** can further include one or more sensors **1682** such as, for example, imaging sensors, accelerometers, touch sensors, and other sensors, as well as NFC components **1684** such as an NFC chip and/or an NFC tag for pairing the electronic device **1670** with one or more other electronic devices. The electronic device **1670** can include an audio module **1677** including hardware components such as a speaker **1685** for outputting audio and a microphone **1686** for detecting or receiving audio. The electronic device **1670** may further include a user interface **1674** to present information to the user and/or receive inputs from the user. As shown in FIG. **16**, the user interface **1674** includes a display screen **1687** and I/O components **1688** (e.g., capacitive or resistive touch sensitive input panels, keys, buttons, lights, LEDs, cursor control devices, haptic devices, and others). The user interface **1647** can also include the speaker **1685** and the microphone **1686**. In embodiments, the display screen **1687** is a touchscreen display using singular or combinations of display technologies and can include a thin, transparent touch sensor component superimposed upon a display section that is viewable by a user. For example, such displays include capacitive displays, resistive displays, surface acoustic wave (SAW) displays, optical imaging displays, and the like.

In general, a computer program product in accordance with an embodiment includes a computer usable storage medium (e.g., standard random access memory (RAM), an optical disc, a universal serial bus (USB) drive, or the like) having computer-readable program code embodied therein, wherein the computer-readable program code is adapted to be executed by the processor **1681** (e.g., working in connection with the operating system **1679**) to facilitate the functions as described herein. In this regard, the program code may be implemented in any desired language, and may be implemented as machine code, assembly code, byte code, interpretable source code or the like (e.g., via C, C++, Java, Actionscript, Objective-C, Javascript, CSS, XML, and/or others).

Thus, it should be clear from the preceding disclosure that the systems and methods offer improved audio playback techniques. The embodiments advantageously enable multiple electronic devices to simultaneously play audio tracks while accounting for network and acoustic latencies. The embodiments improve the user experience by improving the setup of a collective audio playback session as well as reducing the amount of playback delay between or among electronic devices.

This disclosure is intended to explain how to fashion and use various embodiments in accordance with the technology rather than to limit the true, intended, and fair scope and spirit thereof. The foregoing description is not intended to be exhaustive or to be limited to the precise forms disclosed.

Modifications or variations are possible in light of the above teachings. The embodiment(s) were chosen and described to provide the best illustration of the principle of the described technology and its practical application, and to enable one of ordinary skill in the art to utilize the technology in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the embodiments as determined by the appended claims, as may be amended during the pendency of this application for patent, and all equivalents thereof, when interpreted in accordance with the breadth to which they are fairly, legally and equitably entitled.

The invention claimed is:

**1.** An audio playback device comprising:

a communication component adapted to connect the audio playback device to a master device via a wireless connection;

an audio output component adapted to output audio; a data socket; and

a controller module configured to interface with the communication component and the audio output component, and further configured to:

receive, via the wireless connection, a request from the master device including a first system time,

send a response to the master device via the wireless connection,

receive a one-way network latency time value from the master device,

calculate a system clock offset value based on the one-way network latency time value, the first system time, and a slave system time,

join an audio playback session with the master device using the data socket via the wireless connection,

receive, using the audio playback session, at least a portion of an audio file and a playback timing instruction indicating a second system time,

initiate playback of at least the portion of the audio file from the audio output component according to the playback timing instruction and the system clock offset value,

receive, from the master device, a first elapsed time of playback of the audio file on the master device,

compare the first elapsed time of playback to a current second elapsed time of playback of the audio file from the audio output component,

determine that a difference between the first elapsed time of playback and the current second elapsed time of playback exceeds a threshold amount, the threshold amount based on at least a predetermined threshold and the playback timing instruction, and

send, to the master device, an indication that the playback from the audio output component is out of sync.

**2.** The audio playback device of claim **1**, wherein the wireless connection is one of a Wi-Fi Direct connection or a Wi-Fi connection.

**3.** The audio playback device of claim **1**, further comprising:

a user interface adapted to receive input from a user, wherein the controller module is further configured to:

detect user input, via the user interface, corresponding to a playback command request for the audio file,

send the playback command request to the master device, receive a playback command and command timing instructions from the master device, and

modify the playback from the audio output component according to the playback command, the command timing instructions, and the system clock offset value.

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4. The audio playback device of claim 3, wherein the playback command request is to skip to a next audio track, wherein the controller module modifies the playback by:

receiving, using the audio playback session, at least a portion of another audio file and another playback timing instruction from the master device, and  
initiating playback of at least the portion of the another audio file from the audio output component according to the another playback timing instruction and the system clock offset value.

5. The audio playback device of claim 1, further comprising:

a user interface adapted to receive input from a user, wherein the controller module is further configured to: detect a selection of another audio file via the user interface,

send a request to the master device via the wireless connection to switch roles, receive, from the master device via the wireless connection, a notification that the audio playback device and the master device will switch roles.

6. The audio playback device of claim 1, wherein the controller module is further configured to:

receive, using the audio playback session, an additional portion of the audio file from the master device, and initiate playback of the additional portion of the audio file from the audio output component according to the playback timing instruction and the system clock offset value.

7. The audio playback device of claim 1, further comprising:

a user interface adapted to receive input from a user, wherein the controller module is further configured to: announce, via the user interface, a computing audio latency time value for the audio playback device,

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detect, via the user interface, an adjustment request to the computing audio latency time value, and

adjust the playback of at least the portion of the audio file from the audio output component according to the adjustment request.

8. The audio playback device of claim 1, wherein the controller module is further configured to:

measure a computing audio latency time value reflecting an elapsed time for the audio file to propagate through the audio playback device from the controller module to the audio output component, and

adjust the playback of at least the portion of the audio file from the audio output component based on the computing audio latency time value.

9. The audio playback device of claim 1, further comprising:

an audio input component adapted to detect audio, wherein the controller module is further configured to:

receive, using the audio playback session, a sync playback instruction from the master device for playback of audio sync data at a specified time, wherein the master device initiates playback of the audio sync data at the specified time,

initiate playback of the audio sync data from the audio output component at the specified time, and

calculate, from audio detected by the audio input component, an audio latency time value reflecting a time difference in the playback of the audio sync data on the master device and the playback of the audio sync data from the audio output component.

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